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The Marine Laboratory

UNIVERSITY OF MIAMI

54-16

Technical Report
July, 1954

SOME RESULTS OF THE FLORIDA CURRENT STUDY, PRELIMINARY REPORT ON THE GRAND CAYMAN CRUISE
15 November 1953 to 15 May 1954

to

The Office of Naval Research
Contract Nonr-840(01)

CORAL GABLES, FLORIDA

THE MARINE LABORATORY
University of Miami

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by

Ilmo Hela, Frank Chew, and Lansing P. Wagner

F. G. Walton Smith

Coral Gables,
Florida

F. G. Walton Smith,
Director

ML 7904

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I. THE RESEARCH-VESSEL PHYSALIA

The R/V PHYSALIA of the Marine Laboratory, is an 83-foot converted Coast Guard cutter. The following facts give sufficient information on the capabilities of the vessel, and on the facilities on board. Only permanent equipment is listed.

2 main engines: GM Diesel; No. 671 with 70 mm injectors.
2 gasoline driven generators: 220-V, A.C.; 12.5 KVA, 60 cycles
1 75-watt RCA ship to shore radio set
1 RCA Fathometer Jr.
1 UQN-1 Navy Fathometer, (EDO)
1 Loran - ID gb/APN-4
1 electric signal system and speaking tubes
1 heavy weight lifting boom
Ground tackle:
3 Yacthman anchors: 200 lbs; 120 lbs; 100 lbs
2 Danforth anchors: 80 lbs; 40 lbs
1 1500-watt search light
1 electric range: 220-V, A.C.
8 bunks
6-fan blower system for ventilation
2 hydro winches: American Hoist Company with the following approximate capacities:
6000 ft. of 7/32" wire
3000 ft. of 7/32" wire (no wire at present)
1 A-frame and accumulator
1 electric BT Navy Winch plus outboard boom
1 Nansen bottle rack with 12 bottles capacity
1 Anemometer

II. FLORIDA CURRENT STUDIES

The Florida Current has been studied partly by methods previously employed, and partly by new techniques, and on the basis of new ideas. Since, in the main, available finances were devoted to the equipping of the R/V PHYSALIA and for the Grand Cayman Cruise, the regular Florida Current field studies were relatively limited during the period of this report. These will be reported later, in connection with further field studies of the Florida Current.

At this time, only some of the most recent results (which are necessarily preliminary) of the theoretical studies will be given in the following paper on the velocity structure and the transport of the Florida Current.

It is felt that in the future fluctuations in the Florida Current, as a possible origin of the meandering of the Gulf Stream, and changes in the velocity structure and transport of the Florida Current, must be studied extensively by this Laboratory, which is ideally located for such studies.

FURTHER STUDY OF THE VELOCITY STRUCTURE AND TRANSPORT OF THE FLORIDA CURRENT, I.

by

Frank Chew

ABSTRACT

Certain relationships between the sign of time change in the transport of the Florida Current and the sign of the transverse component of the current were assumed. A simplified vorticity equation was then employed to arrive at the conclusion that for equal transport, an increasing transport in the Florida Current tends to increase the vorticity of the current, while a decreasing transport tends to decrease its vorticity.

INTRODUCTION

It was suggested by the writer (1954) that inertial movements along isentropic surfaces may be an essential mechanism in the local time change of transport of the Florida Current (hereafter, F.C.) off Miami. An abbreviated Bjerknes equation for inertial oscillations was used to ascertain the probable direction of the transverse current. Inferences were then made that when the local time change of transport of the F.C. is positive the longitudinal current speed east of the current axis is higher than that west of the axis and vice versa. In the inference process, use was made of the geostrophic relation; inasmuch as the time change of the F.C. was studied, there is reasonable doubt that the relation is applicable. In this note an attempt is made to derive the equivalent conclusions without resort to the geostrophic relation.

The writer is indebted to Prof. R. S. Arthur of the Scripps Institution of Oceanography and Dr. Ilmo Hela for advice and encouragement.

VORTICITY AND TRANSPORT CHANGES

A right handed coordinate system with the positive x axis pointing eastward is chosen. It is assumed, for the present purpose, that when the transport of the F.C. is increasing the transverse current component, u, is positive, and when the transport is decreasing, u is negative; or

$$\frac{\partial}{\partial t}\iint v \, dxdz > 0 \quad ; \qquad u > 0 \qquad (1)$$

$$\frac{\partial}{\partial t}\iint v \, dxdz < 0 \quad ; \qquad u < 0 \qquad (2)$$

Equations (1) and (2) differ from the earlier suggestion that when the transport is increasing u is positive east of the axis and negative west of the axis and vice versa. It is now believed that (1) and (2) are more likely to be true; discussion of this aspect will be made another time.

The equation for the individual change in the vertical component of the absolute vorticity (ζ_a) in horizontal motion is

$$\frac{d\zeta_a}{dt} = -\zeta_a \nabla_H \cdot V - (\nabla\alpha \times \nabla p)_z + (\nabla \times F)_z \tag{3}$$

While the horizontal component of the isoteric-pressure solenoidal effects are large, its vertical component may be safely neglected as is generally done in meteorology; or

$$(\nabla\alpha \times \nabla p)_z \doteq 0 \tag{4}$$

The third term on the right hand side of (3) is the vertical component of the curl of the frictional forces which include wind stress on the ocean surface as well as the lateral friction due to the presence of the walls of the Florida Straits. The width of the F.C. off Miami is less than 80 kilometers and the wind stress may plausibly be taken to be uniform over this relatively short distance. The lateral friction on the Miami side imparts positive vertical vorticity to the F.C. while that at the Cat Cay side imparts negative vertical vorticity; on first approximation, it is assumed that for the F.C. as a whole the positive vorticity cancels completely the negative vorticity; or

$$(\nabla \times F)_z \doteq 0 \tag{5}$$

The assumptions are also made that in the vicinity off Miami:

$$\frac{\partial v}{\partial y} \doteq 0 \tag{6}$$

$$\frac{\partial \zeta}{\partial y} \doteq 0 \tag{7}$$

where ζ is the vertical component of the relative vorticity. The plausability of (6) and (7) remains to be tested by observations.

Substituting equations (4) to (7) in (3), one finds

$$\frac{\partial \zeta_a}{\partial t} + u\frac{\partial \zeta_a}{\partial x} + v\frac{\partial f}{\partial y} = -\zeta_a \frac{\partial u}{\partial x} \tag{8}$$

where $f = 2W \sin \phi$, the Coriolis parameter. Now

$$v\frac{\partial f}{\partial y} = \frac{2W \cos \phi}{r} v \tag{9}$$

where r is the radius of the earth;

and $$\frac{\partial \zeta_a}{\partial t} = \frac{\partial}{\partial t}(\zeta + r') = \frac{\partial \zeta}{\partial t} \qquad (10)$$

and $$\frac{\partial}{\partial x}(u\zeta_a) = u\frac{\partial \zeta_a}{\partial x} + (\zeta_a)\frac{\partial u}{\partial x} \qquad (11)$$

Hence on considering equations (9) to (11), equation (8) becomes

$$\frac{\partial \zeta}{\partial t} = -\frac{\partial}{\partial x}(u\zeta_a) - \frac{2W \cos \phi}{r} v \qquad (12)$$

In words, the equation (12) states that the local time change of the vertical component of relative vorticity is the negative of the sum of the inertial and latitude effects.

Because of (1) and (2) and the constraining effects of the walls of the Florida Straits, there is a point west of the current axis, where, at a constant depth, the magnitude of u is the same as that at a point east of the axis. In fact, there are numerous such pairs of points which may be labelled according to the scheme in Figure I and where the position pairs B_1, b_1, and so on, are taken as fixed in space.

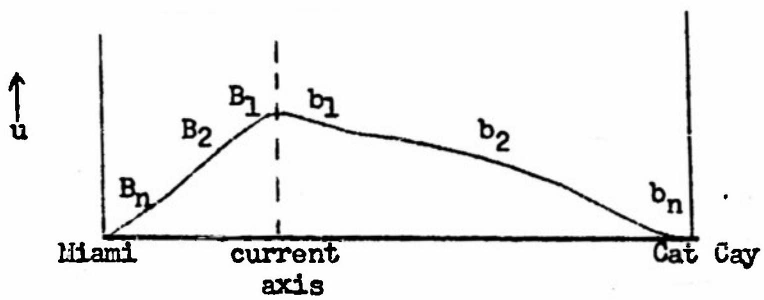


FIGURE I
A scheme for labelling positions having equal u

Let equation (12) be integrated from $x = B_1$ to $x = b_1$ and from the bottom, o, to the surface, h:

$$\frac{\partial}{\partial t}\int_o^h \int_{B_1}^{b_1} \zeta \, dxdz = \int_o^h \left[(u\zeta_a)_{B_1} - (u\zeta_a)_{b_1}\right] dz \quad \frac{-2W \cos \phi}{r} \int_o^h \int_{B_1}^{b_1} v \, dxdz \qquad (13)$$

The integrant in the inertial term may be rewritten as

$$u_{B_1}(f+\zeta)_{B_1} - u_{b_1}(f+\zeta)_{b_1} = u_{b_1}(\zeta_{B_1} - \zeta_{b_1}) \qquad (14)$$

since $u_{b_1} = u_{B_1}$.

Now ζ_{B_1} is positive and ζ_{b_1} is negative always; hence the factor in parentheses on the right hand side of equation (14) is always positive. Equation (13) states that when u is positive, the vorticity of the current in the interval B_1 to b_1 is increased by the inertial effects and decreased by the latitude effects.

Let M and C be the x coordinates of the walls of the Straits at the Miami and Cat Cay sides respectively; and let B_n be a fraction of a kilometer east of Miami and b_n be a similar distance west of Cat Cay. Since u is zero at M and C, it is reasonable to suppose that B_n and b_n, where u_{B_n} equals u_{b_n}, be found at similar distances from M and C. Let equation (12) be integrated from $x_1 = M+B_n$ to $x_2 = C - b_n$ and from the bottom to the ocean surface, h: then taking (14) into consideration, one has

$$\frac{\partial}{\partial t}\int_0^h\int_{x_1}^{x_2}\zeta\,dxdz = \int_0^h u_{x_1}\left[(\zeta_{x_1} - \zeta_{x_2})\right]dz - \frac{2W\cos\phi}{r}\int_0^h\int_{x_1}^{x_2} v\,dxdz \qquad (15)$$

Since the width of the F.C. is some 70 kilometers, the interval of integration along the x axis in equation (15) is essentially the total width of the F.C. With this in mind, the conclusions implicit in equation (15) are tabulated in Table I.

TABLE I

Vorticity and Transport

	Locally increasing total transport ($u > 0$)	Locally decreasing total transport ($u < 0$)
Inertial effects greater than Latitude effects ($A > B$)	Local time increase in the total vorticity of the current	Local time decrease in the total vorticity of the current and at a rate greater than when $A < B$ for equal transport

TABLE I (cont'd.)

Vorticity and Transport

	Locally increasing total transport ($u > 0$)	Locally decreasing total transport ($u < 0$)
Inertial effects less than Latitude effects ($A < B$)	Local time decrease in the total vorticity, but at a smaller rate than when $u < 0$	Local time decrease in total vorticity but at a greater rate than when $u > 0$

Another statement of the conclusions contained in equation (15) is: For equal transports, an increasing transport in the F.C. tends to increase the vorticity of the current, while a decreasing transport tends to decrease its vorticity. A gain in positive vertical component of vorticity in the F.C. implies a decrease in the spatial average of the longitudinal speed west of the current axis or an increase in the average speed east of the axis or both. While a gain in negative vorticity in the F.C. implies an increase in the average speed west of the axis or a decrease in the average speed east of the axis or both. Hence equation (15) is in consonant with the conclusions reached in the previous work and in fact the present conclusions would be the same as the previous ones if such gain or loss in vorticity were to act over a sufficiently long period of time and at sufficiently high rate to mask the vorticity in the current acquired earlier in its life history.

DISCUSSION AND CONCLUSIONS

The use of the vorticity equation has brought out two important points previously omitted. The first point is that when comparing different profiles of the longitudinal speed of the F.C. in relation to its time change in total transport, the comparison is meaningful only when their total transports are equal. The second point is that the gain or loss in positive vorticity due to inertial movements may be overshadowed by the vorticity acquired by the current earlier in its life history; hence in the application of equation (15) care must be taken to avoid period when the amplititude of transport fluctuation of the F.C. is relatively small, where the vorticity history of the current is unknown.

The integration limits of B_1 and b_1 in equation (13) and x_1 and x_2 in equation (15) and the discussion in between appear, offhand, to be unnecessary. Actually the boundary layer problem was involved there. For a viscous fluid, such as water, the kinematic boundary conditions at a fixed rigid wall are generally taken to be that both the normal and tangential components of the current is zero. That these boundary conditions do not strictly apply to study such as the present one is indicated by a consideration of the sea level change

due to standing oscillations in a rectangular basin. For a rise in sea surface at the vertical wall of the basin there must be a vertical tangential current at the wall, yet, by the above boundary conditions the vertical tangential current does not exist. The complex boundary layer phenomenon is far from being well understood; it is mentioned here only to explain the choice of the integration limits x_1 and x_2.

Certain relationships between the sign of time change in transport of the Florida Current and the sign of the transverse component of the current were assumed. A simplified vorticity equation was then employed to arrive at the conclusion that for equal transports, an increasing transport in the F.C. tends to increase the vorticity of the current, while a decreasing transport tends to decrease its vorticity.

Reference

Hela, Ilmo, Frank Chew and Lansing P. Wagner. 1954. Some Results of the Florida Current Study. Marine Laboratory, University of Miami. 54-7.

III. GRAND CAYMAN CRUISE

INTRODUCTION

The field studies made by this Laboratory in the Straits of Florida have shown that the fluctuations in the velocity structure and in the transport of the Florida Current, i.e. a pulsation, are essential characteristics of this current. GEK cable measurements between Key West and Habana show this distinctly. The studies performed by the oceanographers of the A. & M. College of Texas have shown large regional fluctuations in the location of the current pattern north of the Yucatan Channel. Recent studies of the Woods Hole Oceanographic Institution in the eastern part of the Caribbean Sea have given clear evidences for an arhythmic fluctuation of the water transport into the Caribbean Sea. Finally, von Arx' model studies indicate that there exists, in a northern portion of the North Atlantic Anticyclonic Current Eddy, a fluctuation now widely known as the meandering of the Gulf Stream.

Of the discrepancies in the results of several previous studies on the currents in this general area, the following local problem is worthwhile mentioning, since this discrepancy is introduced, apparently by the pulsation of the currents. Parr (1935) states that . . . the Caribbean Current after entering through the Yucatan Channel merely takes the shortest possible path directly to the Straits of Florida, without deviating on the way. Sverdrup (THE OCEANS, 1942) states that.. . . a strong current passes through the Caribbean Sea, continues with increased speed through the Yucatan Channel, bends sharply to the right, and flows with great velocity out through the Straits of Florida. According to surface current charts for Central American Waters (H.O. Misc. 10,690; 1-12), the surface current entering the Gulf of Mexico through the Yucatan Channel seems to continue in the north-northwesterly direction for roughly 150-250 miles and then bends sharply towards the Straits of Florida. This is confirmed by Fuglister (Average Temperature and Salinity at a Depth of

200 Meters in the North Atlantic. Reference No. 53-58. Woods Hole Oceanographic Institution.) Both the average temperature and the average salinity charts require a distinct gradient in the region of the swiftest current. We believe that this apparent discrepancy between the different results is, to a main extent, due simply to the pulsation in the currents: The Caribbean Current, after entering through the Yucatan Channel, probably merely takes, at times, a relatively direct path to the Straits of Florida; at other times, the same Current may bend towards the north before entering the Straits of Florida.

The pulsation of the currents in question can be studied, to a certain extent, as one of the following more limited problems.

Fluctuations in the velocity structure and transport in the Straits of Florida. This problem has been, and will continued to be, approached by the Marine Laboratory both in the field and as a theoretical one. Another effort towards the same goal is made by Wertheim by means of cable between Key West and Habana.

Possible variations in the water amounts brought from the Sargasso Sea into the Florida Current through the Old Bahama Channel, over the Bahamas Bank and through the Northeast and Northwest Providence Channels. This problem will be approached by the Marine Laboratory when funds permit.

Fluctuations in the velocity structure and transport of the Caribbean Current in the northern part of the Caribbean Sea and in the Yucatan Channel. The main goal of the Grand Cayman Cruise was to obtain tentative information for later studies of these fluctuation. Connected with this study must be the study of changes in the position of the main branch of the current between the Yucatan Channel and the Straits of Florida. These studies have also been begun by the A. & M. College of Texas.

A more complete report on the Grand Cayman Cruise of the Marine Laboratory will be given later when the material of the hydrographic stations has been analyzed and when the problems will have been given thorough scientific consideration.

STATIONS

The original plan called for the following hydrographic sections:

(a) Punta Camaron - Grand Cayman
(b) Grand Cayman - Banco Jardines
(c) Banco Chinchorro - Isla de Pinos
(d) Yucatan - Cape San Antonio
(e) 23°45'N.; 85°00'W. - Cayo Jutias
(f) Florida Keys - Habana

In addition to the above, the following independent GEK-BT sections were planned:

(g) Along the western edge of the main current (?) in the Car-

ibbean Sea
(h) Cape San Antonio - Isla de Pinos
(i) Along the western edge of the main current (?) in the Gulf of Mexico
(j) 23°45'N; 85°00'W. - Cape San Antonio
(k) Florida Keys - Habana

Due to the Marine Laboratory's limited funds for hydrographic work, the program was cut down by the elimination of hydrographic section (c) and GEK-BT sections (g) and (i). A stormy sea forced reduction of hydrographic section (d) to a GEK-BT section, and last minute failure of the GEK made it impossible to run section (j).

The actual program can be seen in Figures 2 and 3. Between Isla de Cozumel and Cape San Antonio, and also between Puerto Mariel and Key West, the BT was used every half hour; however, only the hourly station with a GEK fix and BT are indicated on the Figures.

OBSERVER DUTIES

The arrangements of routine work on the Grand Cayman Cruise can be seen from the following list of observer duties prepared for the cruise. As the list shows, the cruise was actually a combined hydrographic-acoustical cruise, of which, however, only the hydrographic portion will be reported here.

Observer Duties on the Grand Cayman Cruise

I. BT Watch

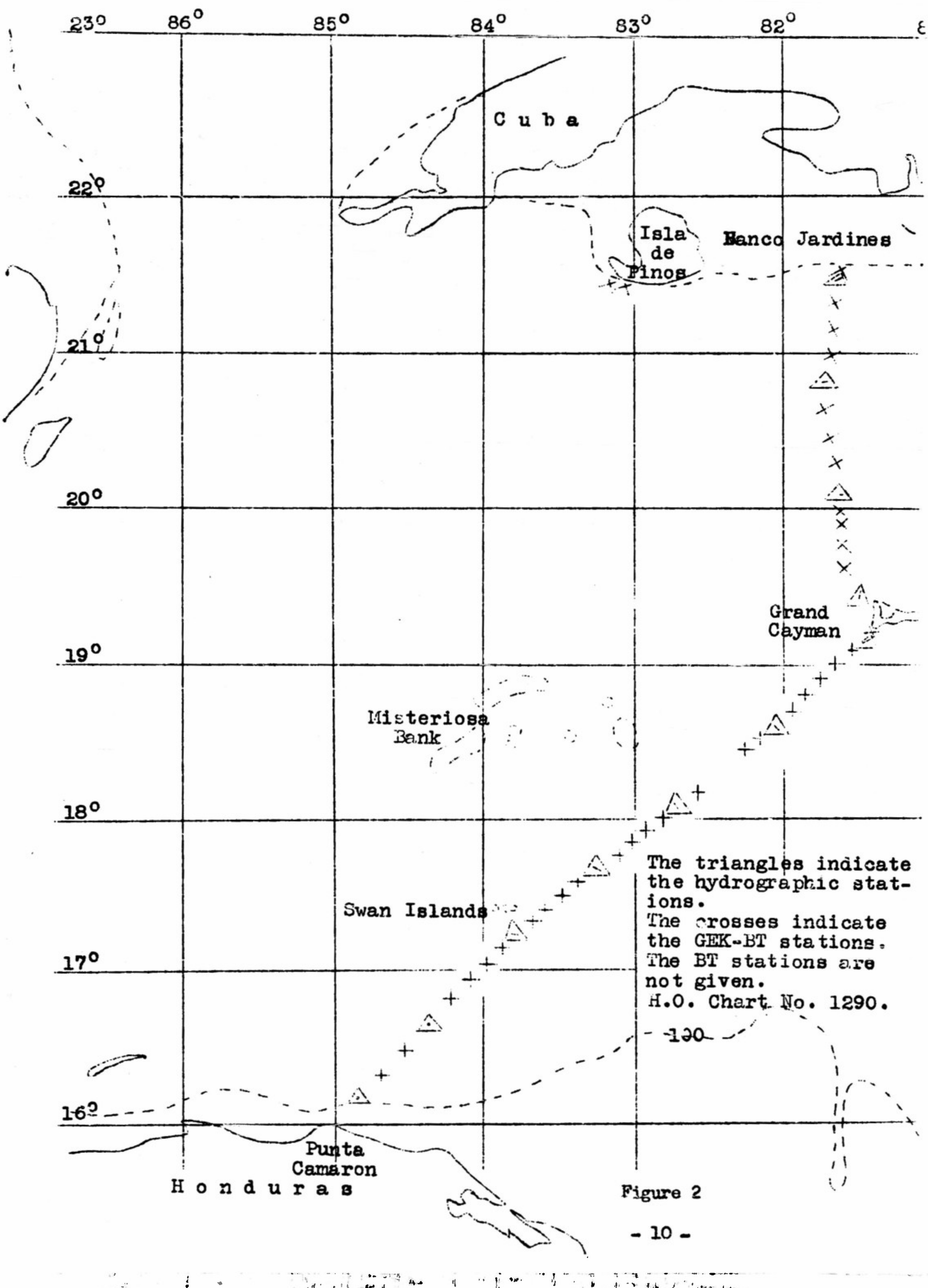
1. (a) Take BT on hour and half hour unless informed otherwise. (Take BT also on each hydro station.)
   (b) Take surface temperature with bucket thermometer.
   (c) Mark fathogram at this time with time and number of station.
   (d) Make meteorological observations.
   (e) Mark BT slide and log sheet.
   (f) Plot temperature-depth profile.
   (g) Fix BT slide.

2. (a) Make GEK fix at quarter past the hour with three minutes on each fix course when new course is steadied.
   (b) Mark fathogram with time and number of station.
   (c) Compute velocity and direction of current.

II. Hydro Station Watch

1. Preparation

A. Hydrographic Work



23°
86°
85°
84°
83°
82°
22°
21°
20°
19°
18°
17°
16°
Cuba
Isla de Pinos
Banco Jardines
Grand Cayman
Misteriosa Bank
Swan Islands
Punta Camaron
Honduras
100
The triangles indicate the hydrographic stations.
The crosses indicate the GEK-BT stations.
The BT stations are not given.
H.O. Chart No. 1290.

Figure 2

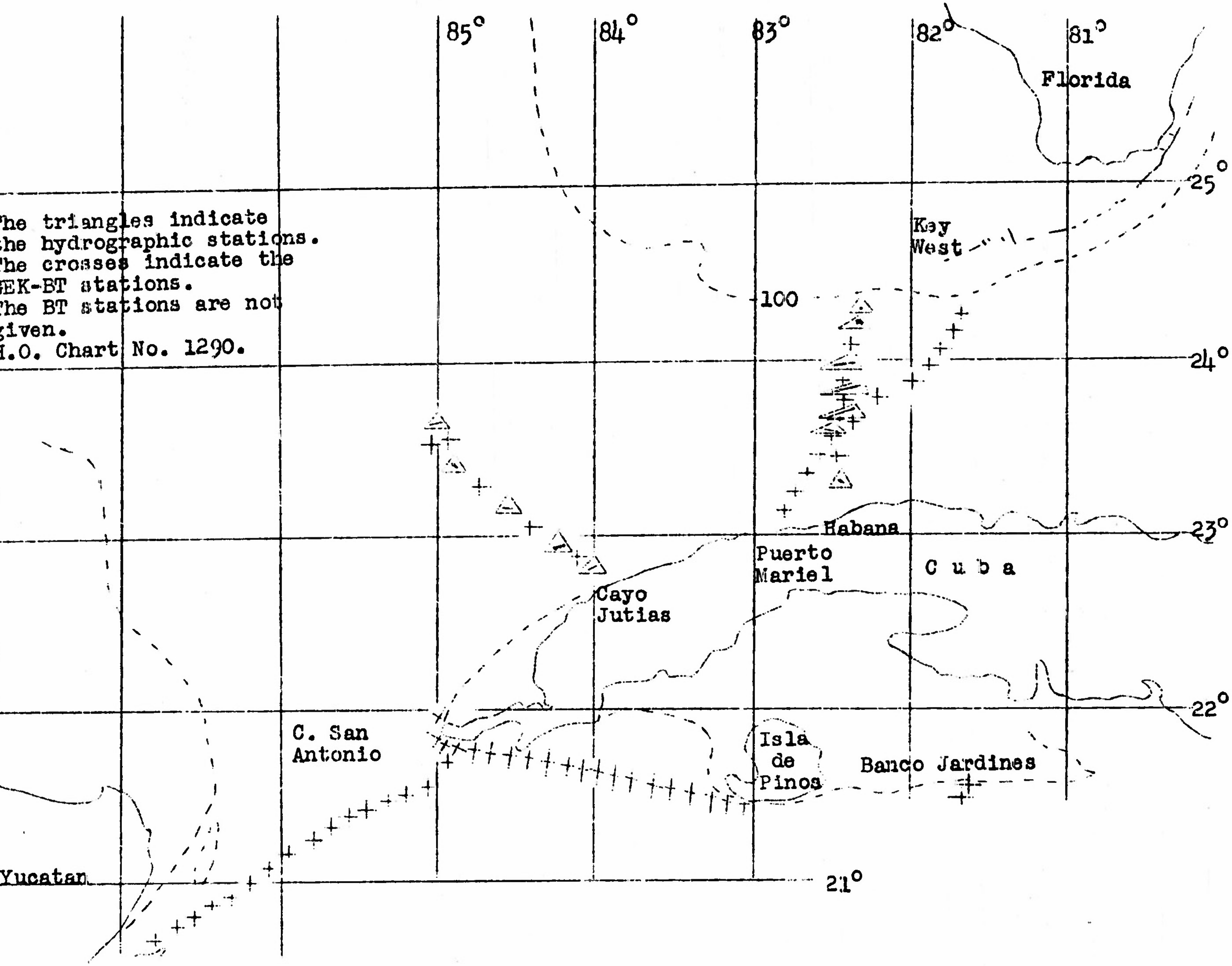

The triangles indicate
the hydrographic stations.
The crosses indicate the
GEK-BT stations.
The BT stations are not
given.
H.O. Chart No. 1290.
85°
84°
83°
82°
81°
25°
24°
23°
22°
21°
Florida
Key
West
100
Habana
Puerto
Mariel
C u b a
Cayo
Jutias
C. San
Antonio
Isla
de
Pinos
Banco Jardines
Yucatan

Figure 3

(a) Have predetermined the desired depths of bottles, estimate the probable wire angle, and decide on the reading of the meter wheel at which bottles are attached.
(b) Compute and mark $1/Qr_m$ for each depth with unprotected thermometer.
(c) Check on condition of Nansen bottles. Close petcocks and air vents of bottles.
(d) Check on condition of thermometers. (When thermometers are reversed in the air they ought to record the same as the auxiliary thermometer, roughly.)
(e) Get sample bottles ready and record numbers.
(f) Turn off GEK, mark time and hydro station number, and (after having informed the man at wheel) pull in cable leaving the electrodes soaking.
(g) Mark fathogram with time and station number and record sonic depth on hydro station log.
(h) Record time "Start" of the station.
(i) Take BT.

B. Acoustic Work
(a) Check recording equipment.
(b) Mark fathogram with time and station number.

2. <u>On Station</u>

A. First cast
(a) Nansen bottles down. Record time "Stop" when done.
(b) Record wire angle. Estimate from the wire angle and note true depths of bottles with unprotected thermometers.
(c) Wait 5 minutes.
(d) Send messenger. Record time "Mess". Allow time for all the messengers of the cast.
(e) Nansen bottles up. Record time "Up" when starting and "In" when finished.
(f) Check $D = (T_u - T_w) \times (1/Qr_m)$ for each bottle with unprotected thermometer; if results mainly erroneous, repeat cast.
(g) Take surface temperature with bucket thermometer.
(h) Take surface water sample.
(i) Make meteorological observations.
(j) Secchi disc, if used.

B. After the first (Acoustic work)
(a) Quiet ship. Turn off ship's generators.
(b) Record sine wave and white noise calibration signals.
(c) Record ambient noise at 20 and 200 foot depths.
(d) Log all pertinent data.

C. Before the second cast
(a) Draw salinity and oxygen samples.
(b) Oxygen determinations.
(c) Read temperatures after a half hour.

Second cast in the same fashion as the first cast.

3. After the final cast when leaving the station

(a) Stream GEK cable (after having informed the man at wheel), turn instrument on and mark time.
(b) Draw salinity plus oxygen samples.
(c) Oxygen determinations.
(d) Read temperatures after a half hour or at convenience.

III. Special Hydrographic Duties

1. Plot the course on working chart and enter positions on the BT and GEK logs and hydrographic logs.
2. Correct the thermometer readings and plot temperatures against depth.
3. Plot oxygen-depth profile.

IV. Special Acoustic Observations

1. At all times tend EDO and Fathometer Jr. to bring in scattering layers and bottom.
2. When approaching suitable banks, run noise profile recording (3-5 hours
3. In a selected shallow (25-50 fm) shelf area record depth dependence of noise (2-4 hours).
4. Record noise when possible during

(a) Approach of rain squall
(b) Thunderstorm
(c) Approach (1½ mile, to 5 miles) ships.

V. Plankton studies

1. Surface tows whenever possible.
2. Bottom to surface plankton tows. If possible these tows will be made in two flights, one from bottom to mid-depth point and another from mid-depth to surface.
3. Dip netting with night-light whenever possible.

In the hydrographic field work this Laboratory uses the log form (appearing as page 14) for the original and corrected hydrographic observations. Other forms, used for the hydrographic computations, are forms for computation of: anomaly of specific volume; anomaly of dynamic height; relative currents between stations; volume transport between stations. These forms, which might be of practical value to some readers of these reports, will be included as part of the next semiannual report on this contract.

The following persons took part in the Grand Cayman Cruise:

MARINE LABORATORY—UNIVERSITY OF MIAMI

Vessel ______
Cruise ______
Station ______
Date ______
Observer ______

Lat. ______ N. } Loran or D. R.
Long. ______ W. }
Sonic Depth (______)
______ Fm. —
______ M.

Wea. ______
Clouds ______ /10
Wet Bulb ______
Dry Bulb ______
Wind Dir. ______
Wind Force ______

B. T. No. ______
Slide No. ______
GEK Fix No. ______
Sea ______
Swell ______
Secchi Disc ______

Cast No.	Obs. Wire Angle	Time (Zone:) Start	Stop	Mess.	Up	In
1.						
2.						
3.						

Cast	Desired Depths	Prob. Wire Angle	Wire Length	Meter Wheel	Frame No.	Protected Thermometer No.	T′	t	△ T	$T_{w,1}$	Righthand Thermometer No.	T′	t	△ T	T	u	Corr. Temp. T_w	Calculation of Depth $T_u - T_w$	Calc. Depth	Wire L.— Calc. D.	Corr. Depth	Bottle Numbers, etc. Cl No.	Sal. ‰			
Blk.	—	—	—	—	—	—					—		—	—	—	—	.	—	—	—	O					
1.																										

REMARKS:

OVER

Dr. Ilmo Hela	
Mr. Lansing P. Wagner	
Mr. David O'Berry	
Mr. Kou Walter	
Mr. August Pirts	
Mr. Jack Best	
Mr. Clarence P. Carpenter	(Miami to Isla de Pinos)
Mr. Joseph Richard	(Miami to Belize)
Mr. Paul Ferris Smith	(Belize to Miami)

TEMPERATURE-DEPTH PROFILES

On pages 16 - 20 the temperature depth profiles, obtained from the 900 foot bathythermograph lowerings, are given for the following sections:

17°34.5' N., 83°23.5' W. - 18°32.0' N., 82°11.0' W. (Through the main branch of the Caribbean Current close to Swan Islands.) (Figure 4)

Isla de Cozumel - Cape San Antonio. (Yucatan Channel.) (Figure 5)

23°45' N., 85°00' W. - Cay Jutias. (Northwest of Cuba.) (Figure 6)

Marquesas Keys - Habana. (Figure 7)

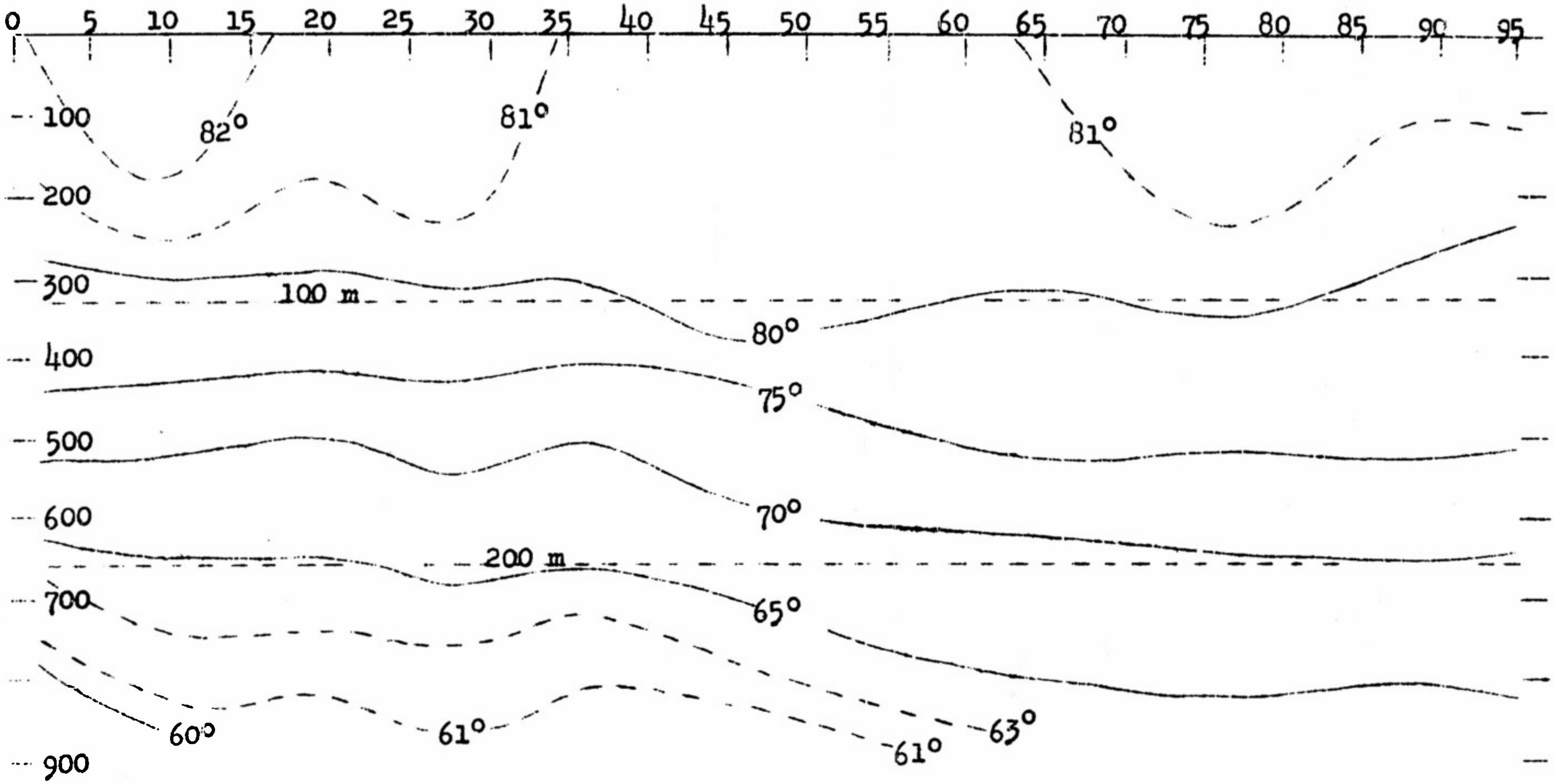
Key West - Puerto Mariel. (Figure 8)

All observations are referred to a straight line, relatively accurately perpendicular to the main direction of the current. As an abscissa, the distances are given in nautical miles along the above projection line; the scale is the same in all these drawings. As ordinate the depths in feet are given.

The maximum slope of the isothermal surfaces at 200 meters' depth is roughly the following:

1.13×10^{-3}	(Close to Swan Islands)
1.05×10^{-3}	(Yucatan Channel)
No slope	(Northwest of Cuba)
2.86×10^{-3}	(Between Florida Keys and Cuba)
3.90×10^{-3}	(Between Florida Keys and Cuba)

Although these results are based only on temperature observations, the dissimilarity between the Caribbean Current close to the Swan Islands or in the Yucatan Channel, and the Florida Current (in the Straits of Florida) is clearly demonstrated. On the other hand, there is a remarkable similarity in the temperature distribution in the main branch of the Caribbean Current near Swan Islands, and in the Yucatan Channel. At least, the temperature distribution between surface and the depth of 900 feet seems to indicate that there was nothing like an eastbound current northwest of Cuba between Cayo Jutias and the

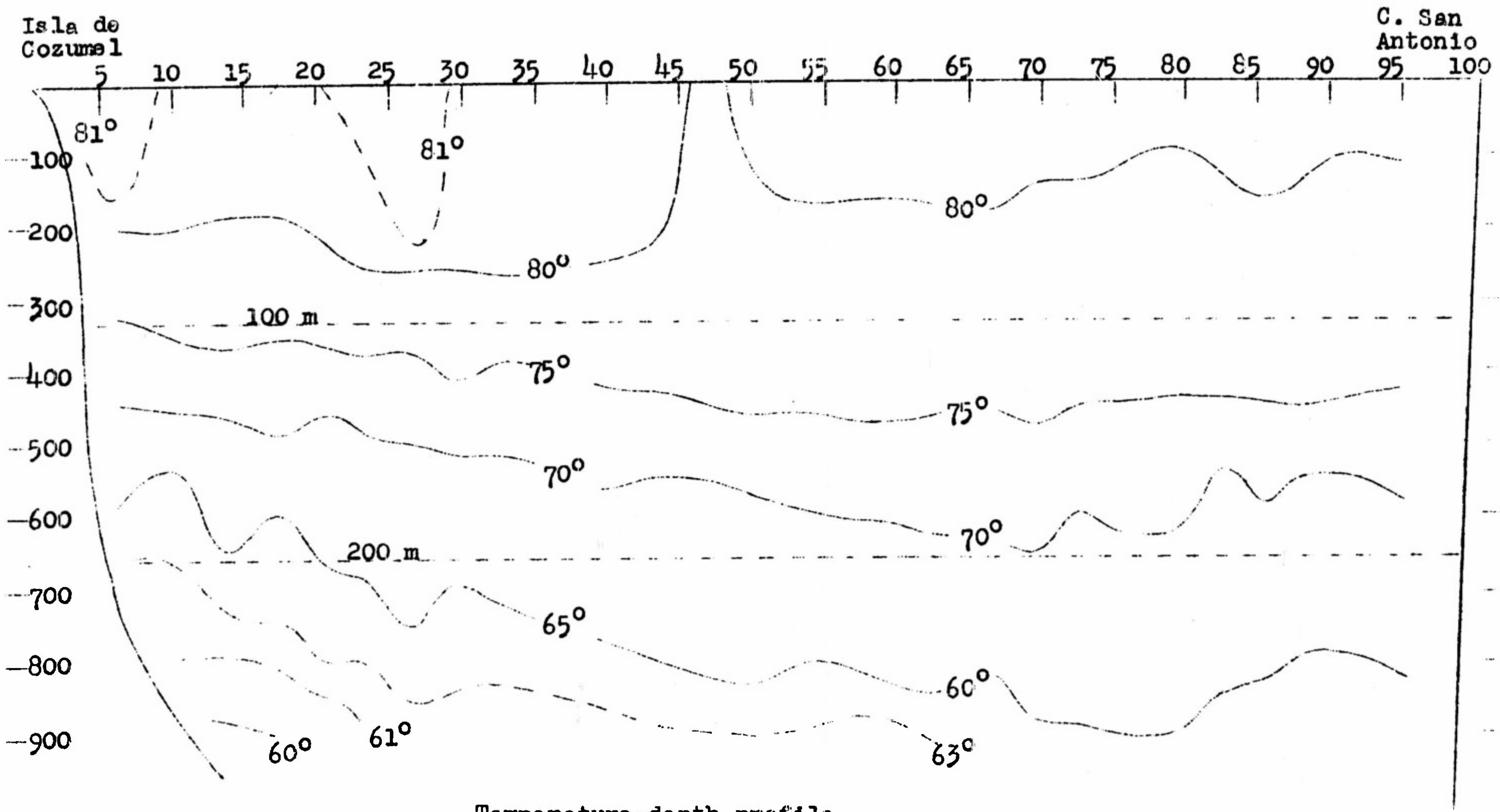


17° 34.5' N.,
83° 23.5' W.

Temperature-depth profile
17° 34.5' N., 83° 23.5' W. -
18° 32.0' N., 82° 11.0' W.
April 11-12, 1954.

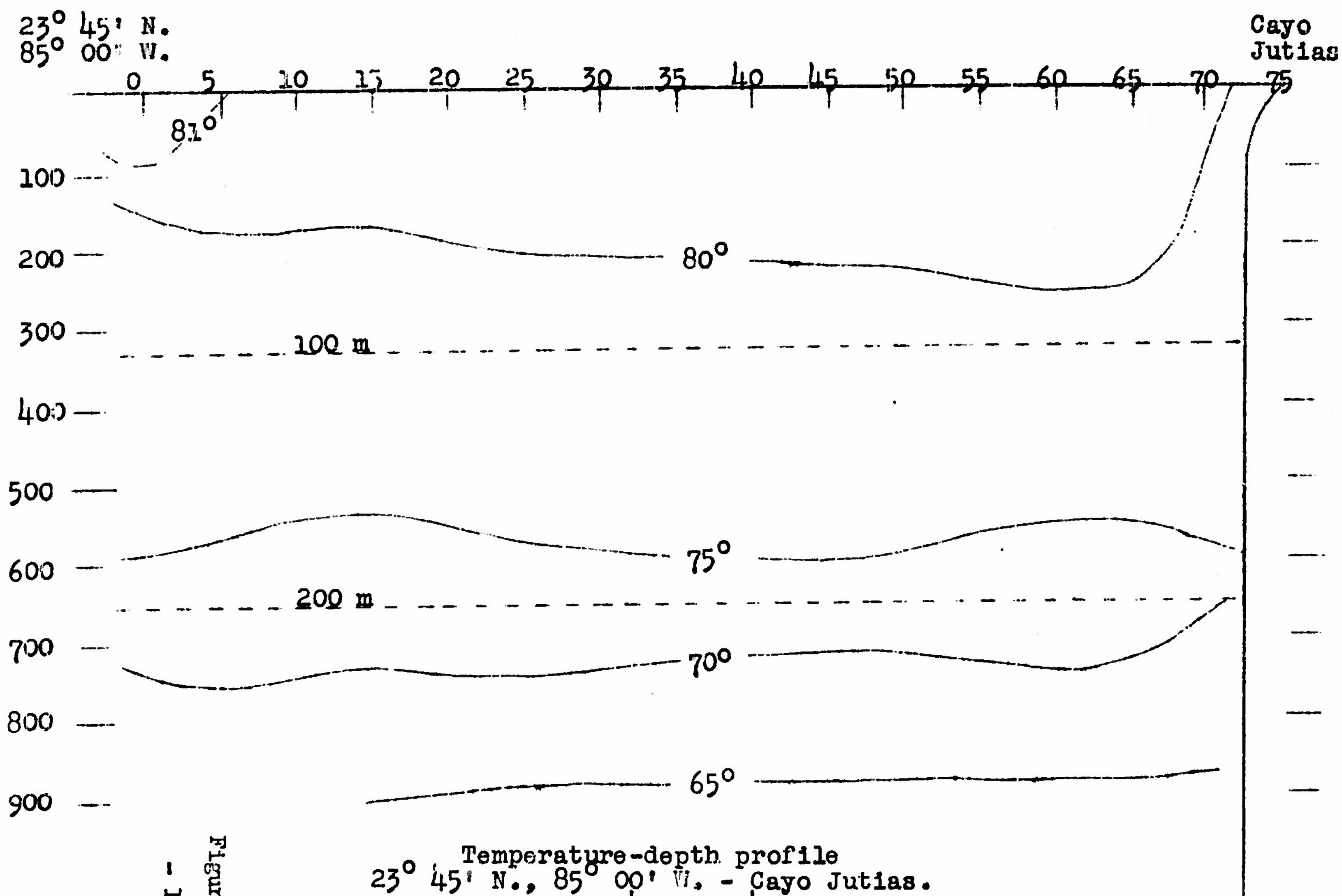
18° 32.0' N.,
82° 11.0' W.

Figure 4



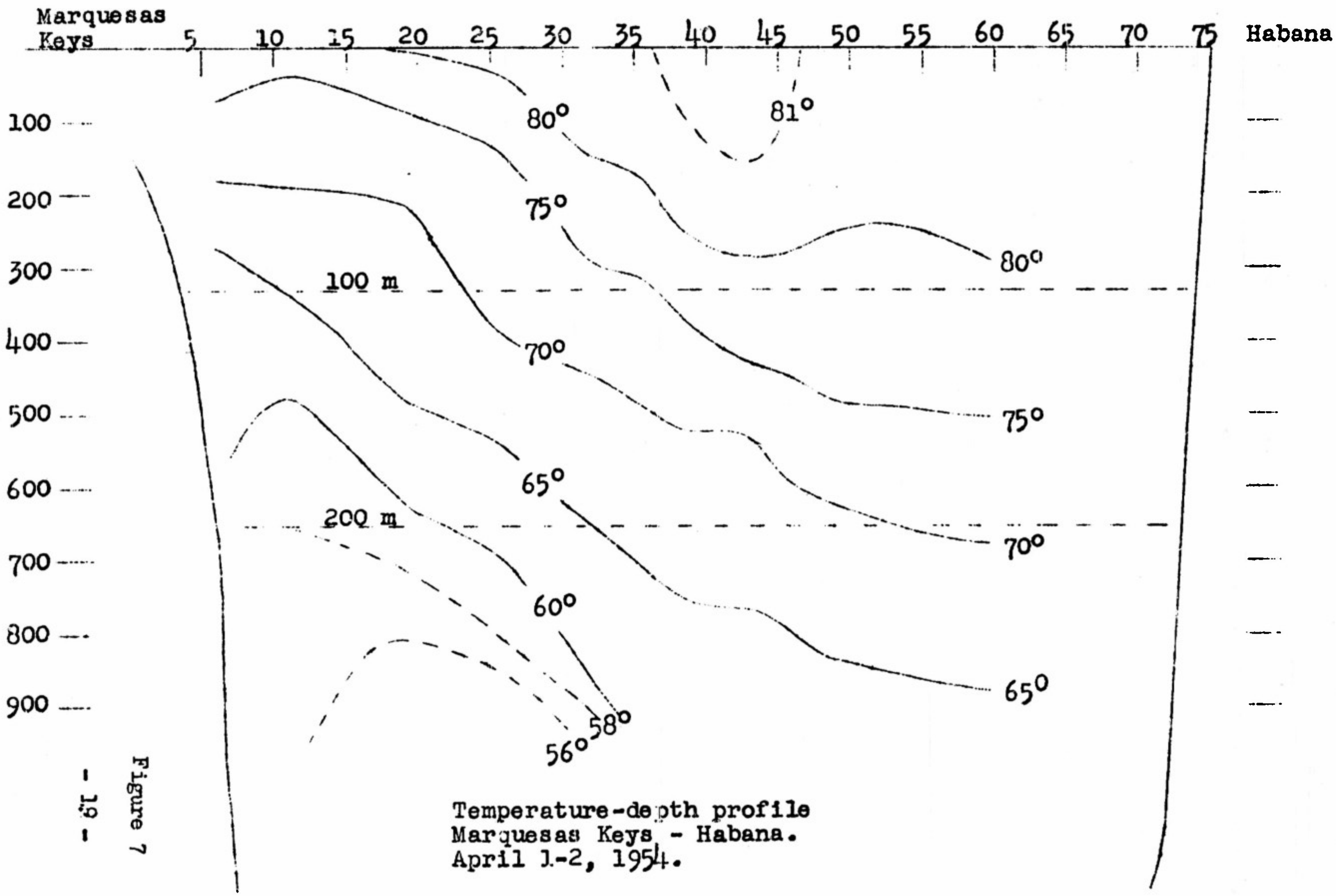
Temperature-depth profile
Isla de Cozumel - Cape San Antonio.
April 19-20, 1954.

Figure 5



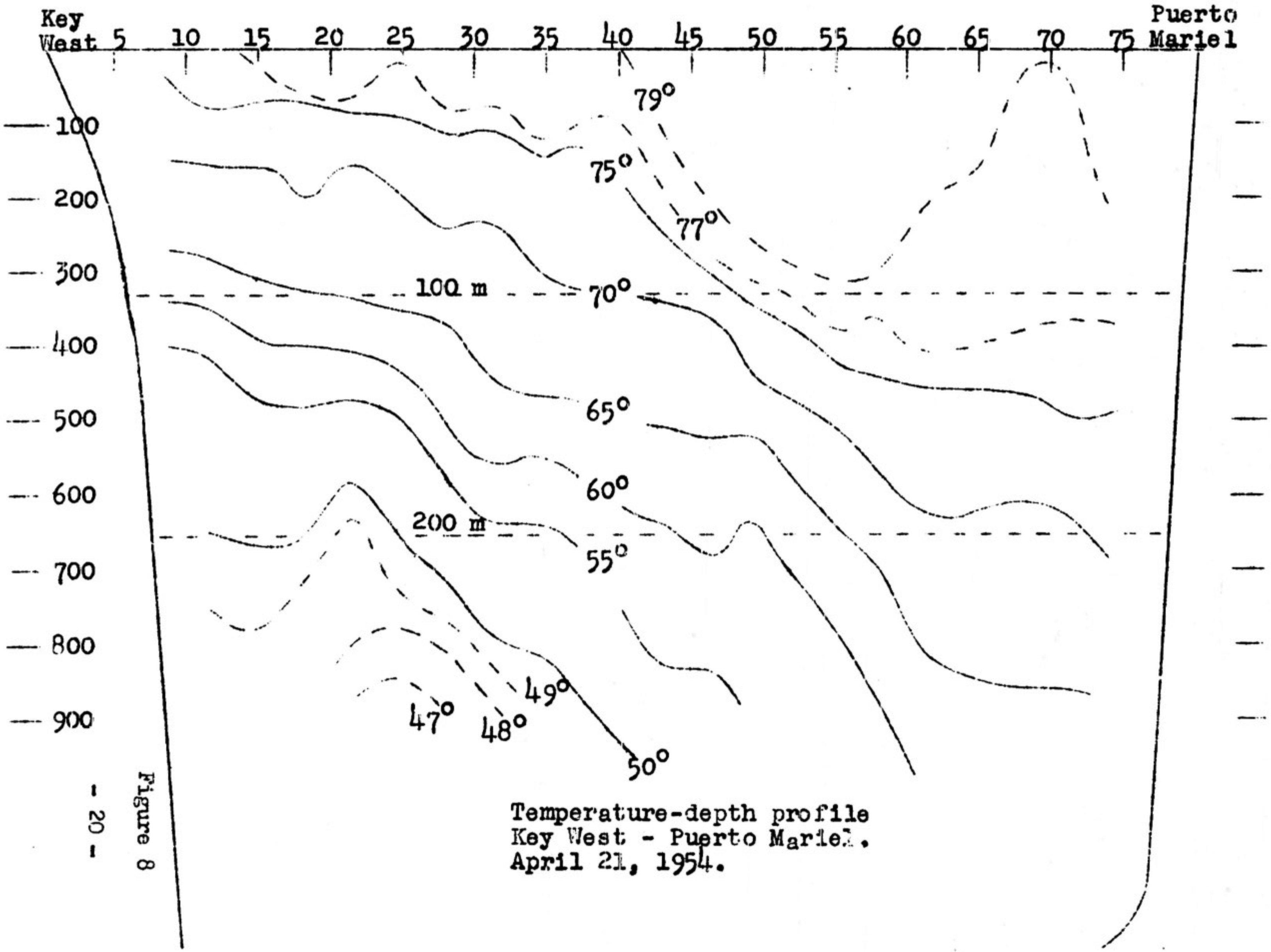
Temperature-depth profile
23° 45' N., 85° 00' W. - Cayo Jutias.
April 4-5, 1954.

Figure 6



Temperature-depth profile
Marquesas Keys - Habana.
April 1-2, 1954.

Figure 7



Temperature-depth profile
Key West - Puerto Mariel.
April 21, 1954.

Figure 8

point 23° 45'., 85° 00' W. We shall return to this particular in the following pages. The axis of the Florida Current is apparently rather close to the Florida Keys during April 1 - 2, but south of the middle portion of the Straits, April 21. This change, as an indication of the pulsation, will also be considered later in this report.

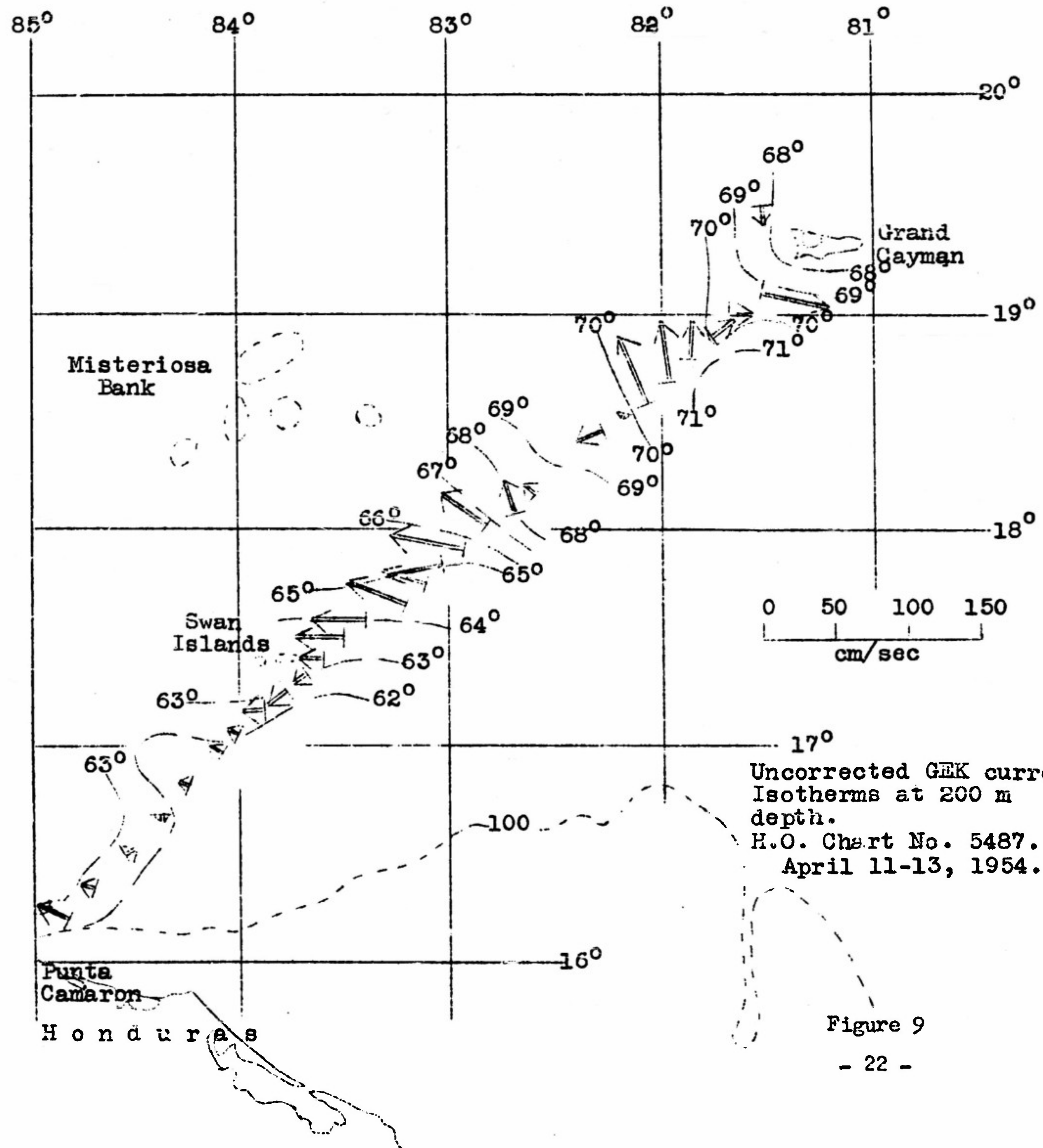
GEK CURRENT VECTORS: TEMPERATURES AT 200 METERS

On pages 22 - 28 the regional distribution of the surface current vectors, measured by the geomagnetic electrokinetograph (GEK) is given as Figures 9 - 15. To check the reliability of the direction of these vectors, the isotherms at 200 meters depth have been indicated. In general, for an observer facing downstream, the temperatures ought to be higher on the right side of the current. As can be seen from the Figures, the direction of the GEK vectors in almost every case coincides very well with the most probable direction of the isotherms. Actually, this was true even in those exceptional cases where weak currents and a rough sea made steady steering of the vessel difficult.

The magnitudes of the GEK-indicated surface current vectors are systematically less than actual, since the K-factor has not been applied. It might be correct to assume that in the open Caribbean Sea the K-factor is relatively small, and therefore the given speeds are too low by only 10 or 20 per cent. In the Yucatan Channel the error might be a little larger, and in the Straits of Florida the true speeds must be at least 30 or 40 per cent larger than shown. The K-factor could not be computed, since it was found that either the hydrographic stations made estimation of the average drift of vessel impossible, or the current was too small compared with the windage, and, further, the actual distance from land to land was too long. Only in the last GEK-BT section between Puerto Mariel and Key West would an estimation of the K-factor have been possible. Unfortunately, rough sea made it impossible in this case, also.

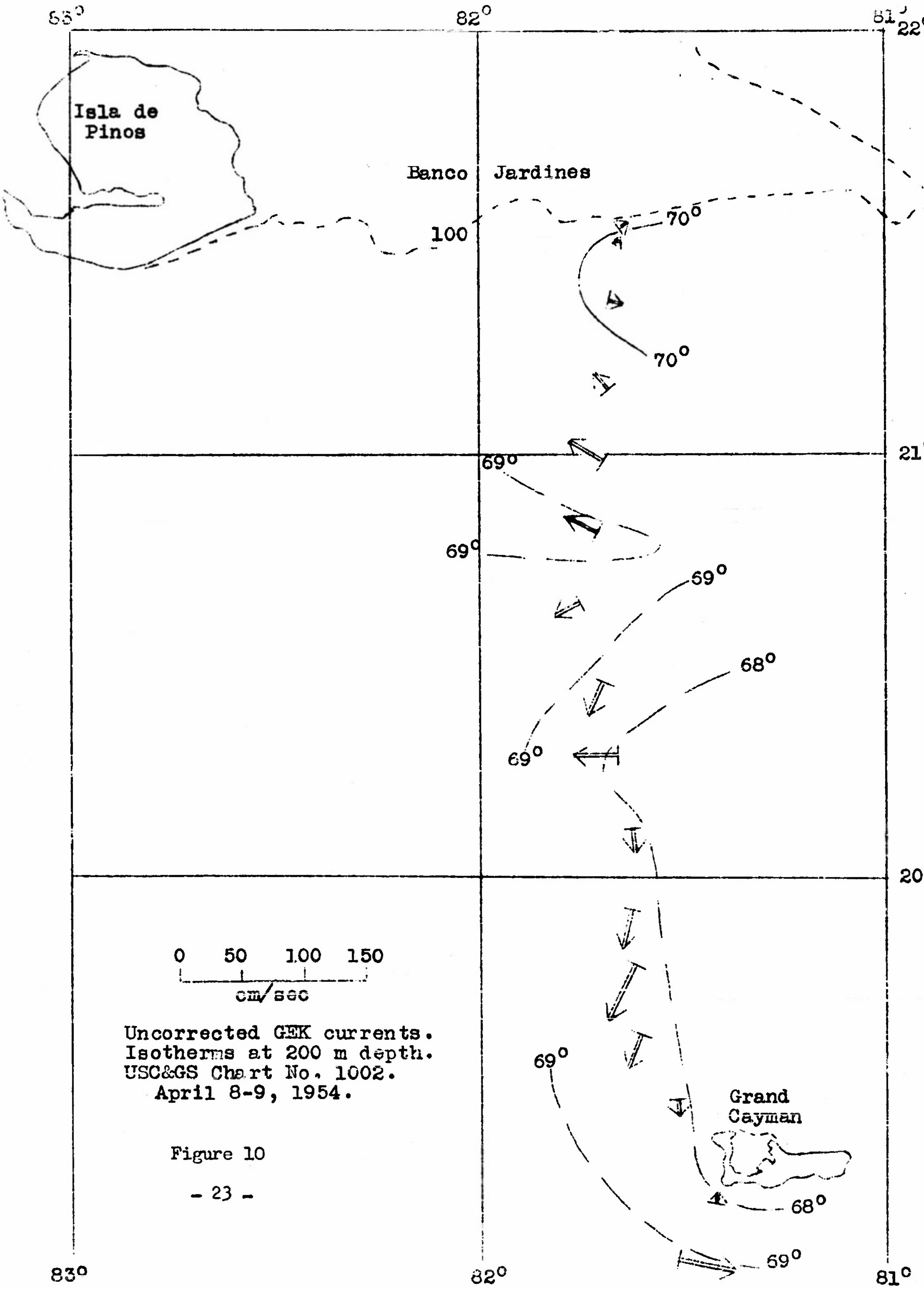
In all the Figures giving the GEK currents, the scale of the speeds is the same, though the geometric distances are not the same, making the speeds comparable. Among interesting details are the following. The main branch of the Caribbean Current passes the section between Honduras and Grand Cayman north of Swan Islands and probably south of the Misteriosa Bank. The direction of current is roughly 280°, and the maximum current slightly above one knot. Another relatively swift current seems to exist along the longitude 82°, towards 340° roughly. However, a cyclonic counter current runs around the Grand Cayman.

In the Yucatan Channel the main branch of the Caribbean Current very closely follows the edge of the shallow western portion of the Channel. The maximum observed speed is roughly 2 knots, or slightly less. In the eastern portion of the Yucatan Channel the waters flow from the section south of Cuba southwest or west-southwest.



Uncorrected GEK curren·
Isotherms at 200 m
depth.
H.O. Chart No. 5487.
April 11-13, 1954.

Figure 9



Uncorrected GEK currents.
Isotherms at 200 m depth.
USC&GS Chart No. 1002.
April 8-9, 1954.

Figure 10

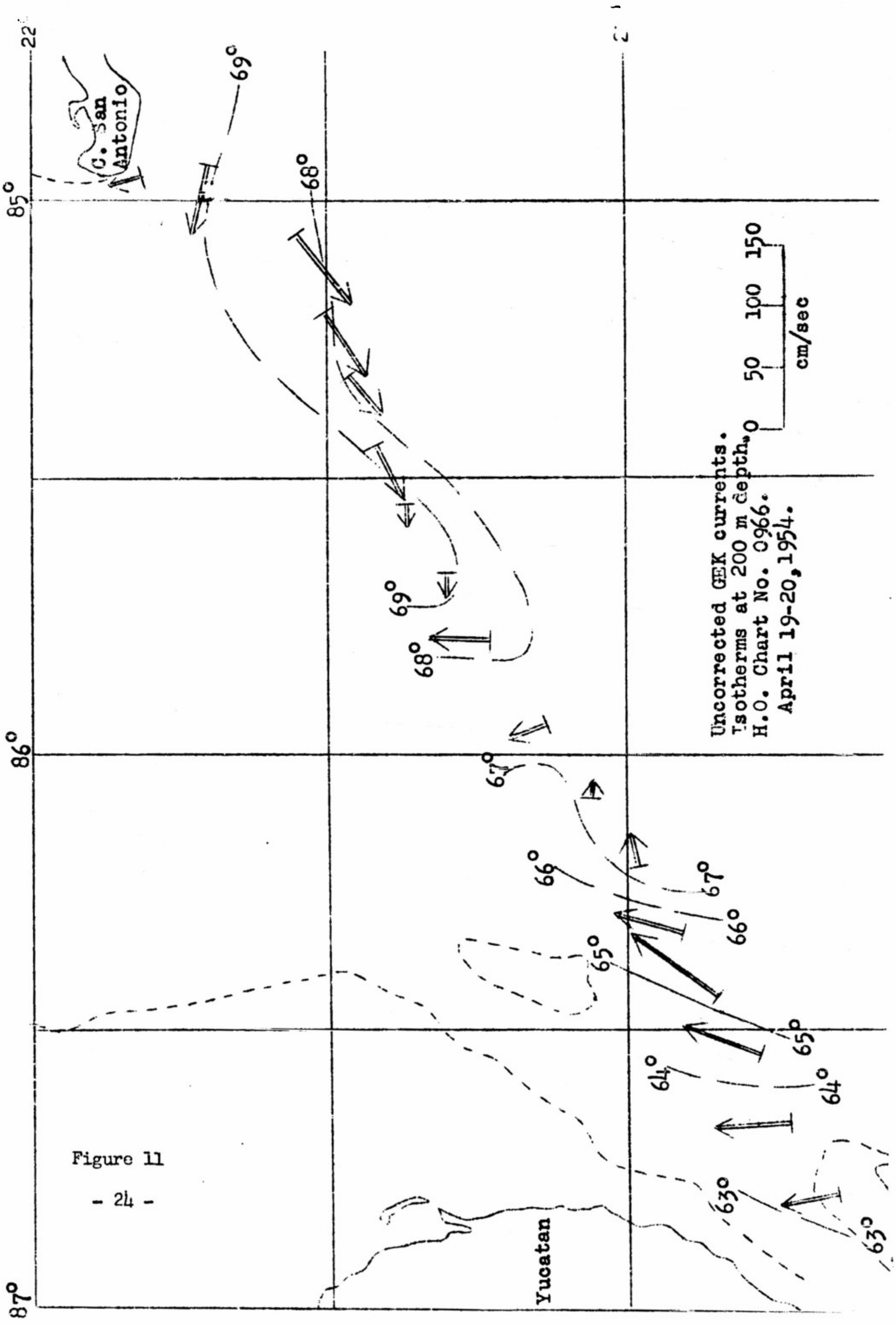

87°
86°
85°
22
C. San Antonio
Yucatan
69°
68°
69°
68°
67°
66°
65°
64°
63°
67°
66°
65°
64°
63°
Uncorrected GEK currents.
Isotherms at 200 m depth.
H.O. Chart No. 0966.
April 19-20, 1954.
0 50 100 150
cm/sec

Figure 11

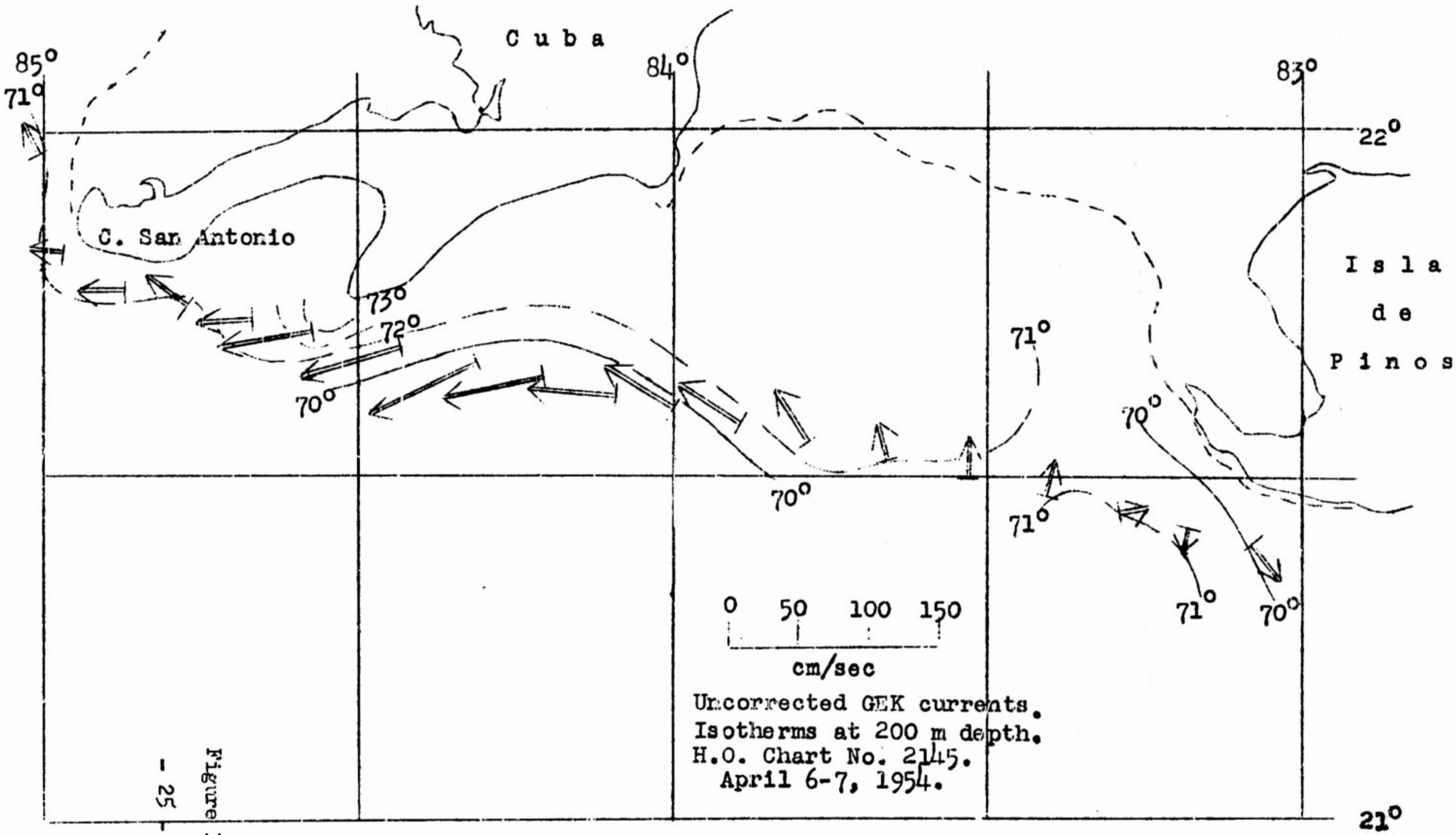
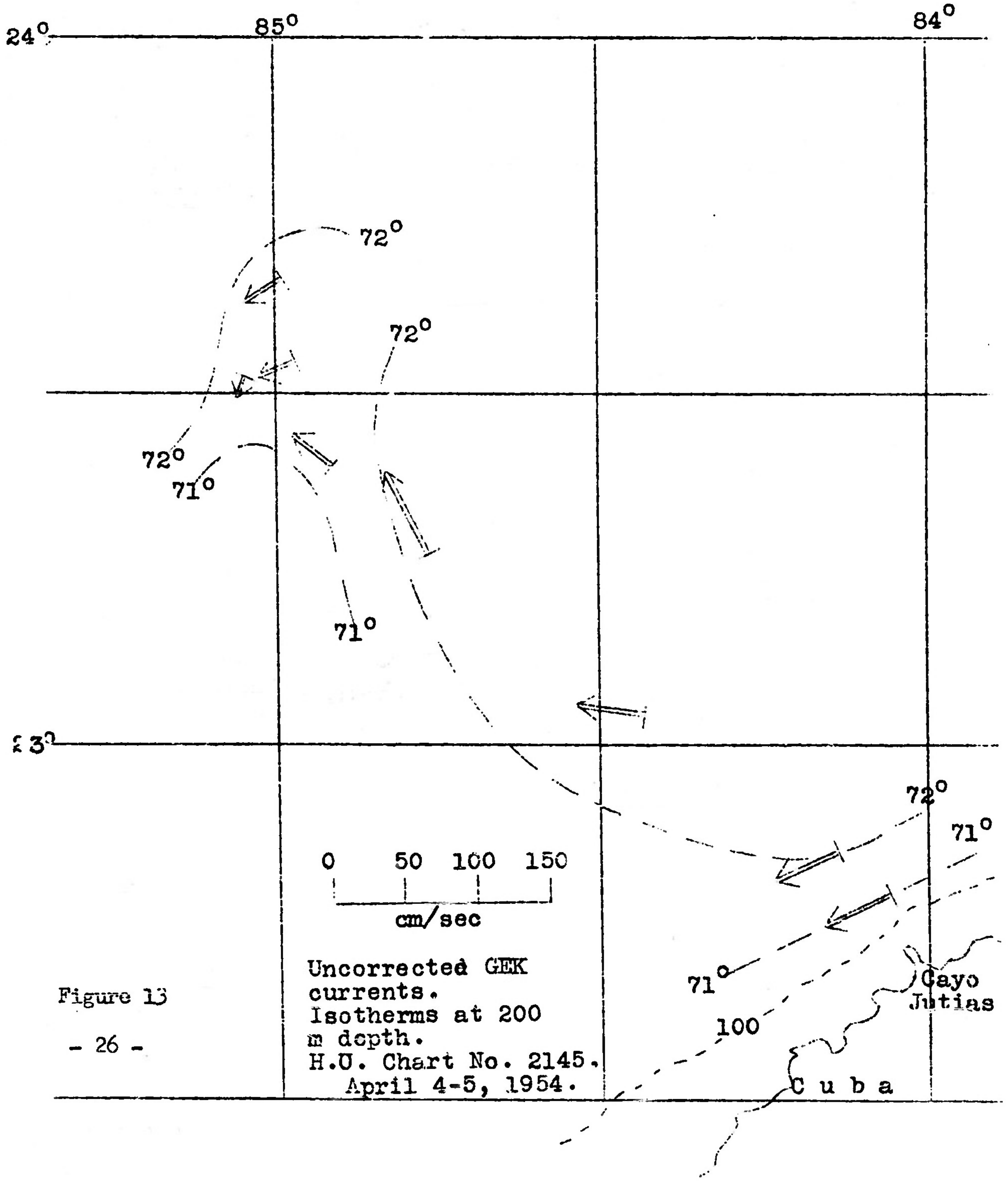

Cuba
C. San Antonio
Isla de Pinos
85°
84°
83°
22°
21°
71°
73°
72°
70°
71°
70°
71°
71°
70°
70°
0 50 100 150
cm/sec
Uncorrected GEK currents.
Isotherms at 200 m depth.
H.O. Chart No. 2145.
April 6-7, 1954.

Figure 12



Uncorrected GEK currents. Isotherms at 200 m depth. H.U. Chart No. 2145. April 4-5, 1954.

Figure 13

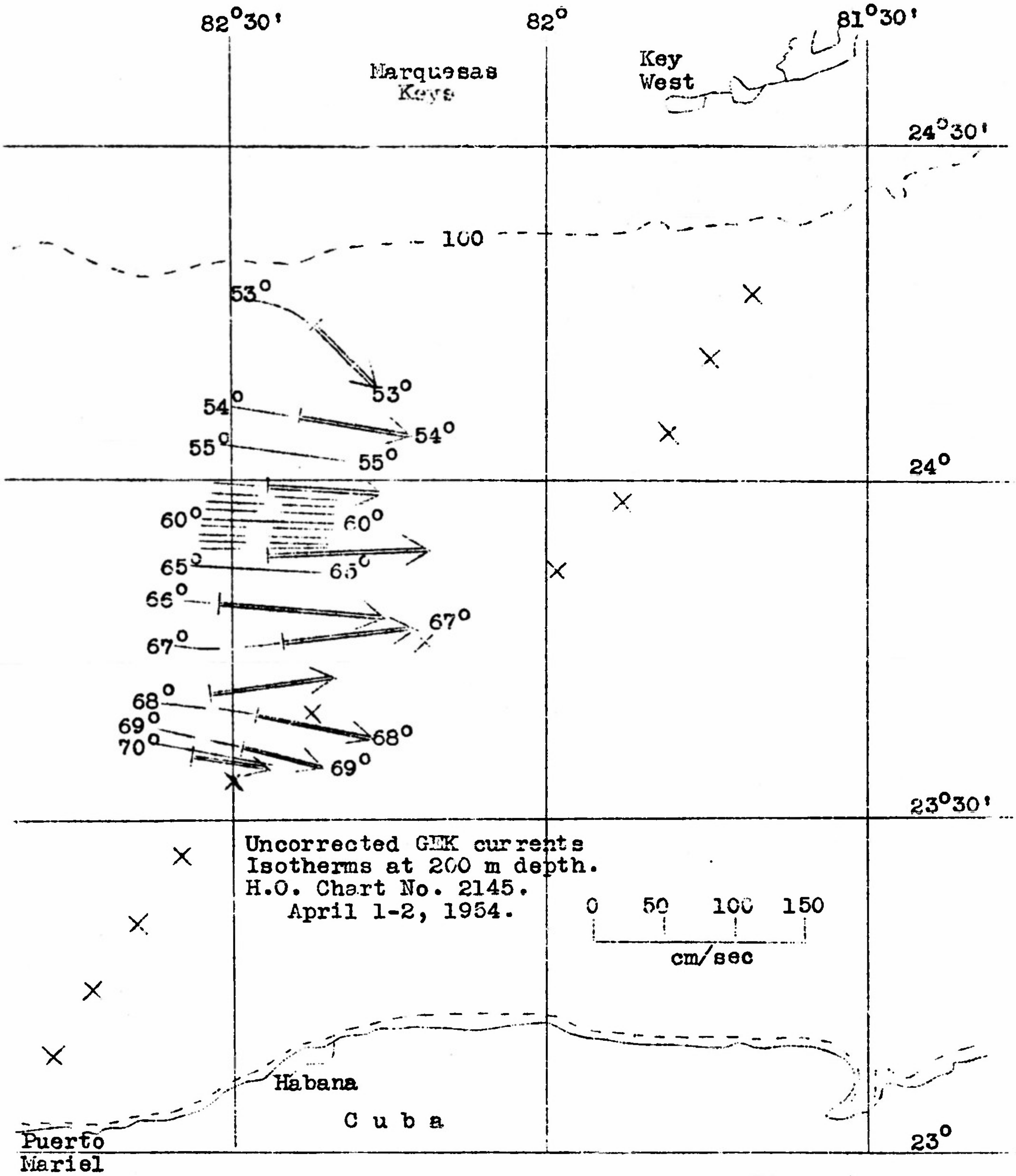

82°30'
82°
81°30'
Marquesas Keys
Key West
24°30'
100
53°
53°
54°
54°
55°
55°
24°
60°
60°
65°
65°
66°
67°
67°
68°
68°
69°
69°
70°
23°30'
Uncorrected GEK currents
Isotherms at 200 m depth.
H.O. Chart No. 2145.
April 1-2, 1954.
0 50 100 150
cm/sec
Habana
Cuba
Puerto Mariel
23°

Figure 14

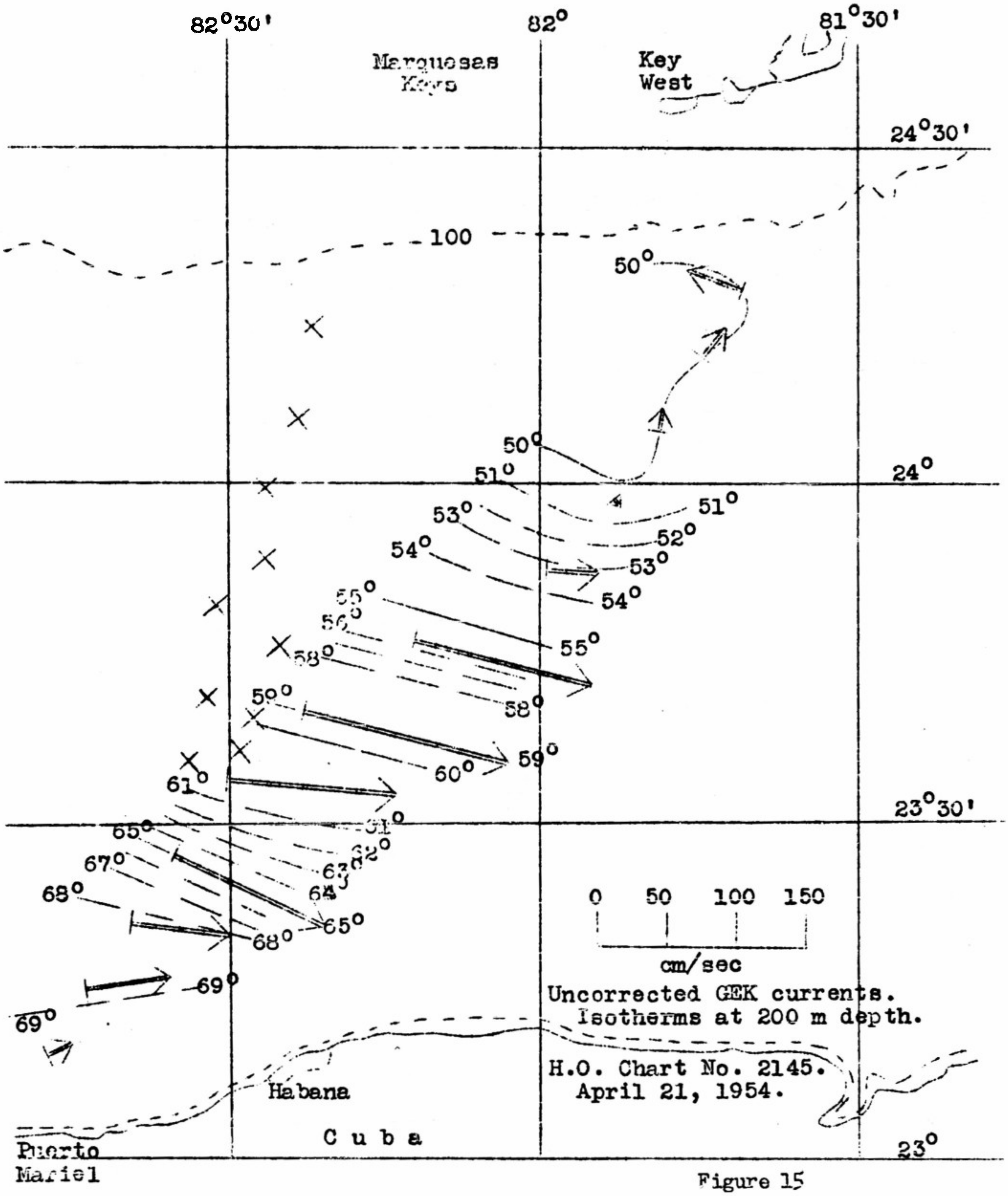

82°30'
82°
81°30'
Marquesas Keys
Key West
24°30'
100
50°
50°
51°
24°
51°
53°
52°
54°
53°
54°
55°
55°
58°
59°
59°
60°
61°
23°30'
65°
67°
68°
65°
68°
69°
69°
0 50 100 150
cm/sec
Uncorrected GEK currents.
Isotherms at 200 m depth.
H.O. Chart No. 2145.
April 21, 1954.
Habana
C u b a
23°
Puerto
Mariel

Figure 15

Northwest of Cuba, at least during April 4 - 5, and between Cayo Jutias and the point 23° 45' N., 85° 00' W., the surface waters were moving west, though relatively slowly. There is no indication whatsoever of an easterly current.

As to the currents indicated by the GEK between Florida Keys and Habana, the most remarkable phenomenon is the transfer of the axis of the Current from the northern portion of the Straits on April 2nd to the southern part of the Straits on April 21st. On the 21st, a distinct westerly countercurrent was found along the Keys and it is important to note in this connection that the wind was easterly and rather strong.

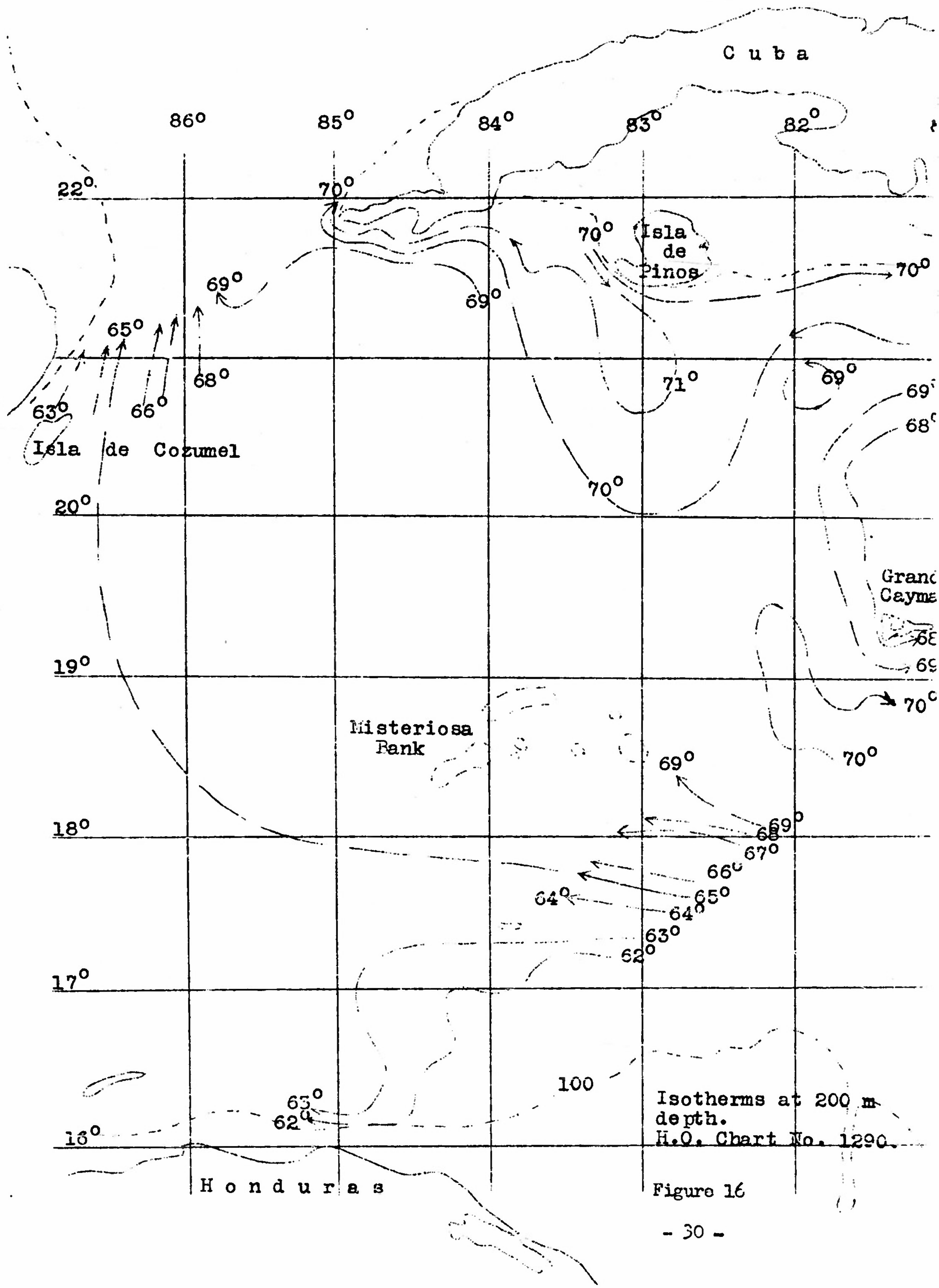
CONCLUSIONS AND SUGGESTIONS

The most probable surface currents for April 1 - 5, 1954, and for April 19 - 21, 1954, between Florida Keys and Habana, are given in Figures 17 and 18. The change in location of the main current from the northern part of the Straits of Florida to the southern part can be seen from these Figures and from Figure 19, where the temperatures at 100- and 200-m. depth are shown. The most probable surface currents of the northern Caribbean Sea during the period in question is shown in Figure 16, which was based both on the GEK-indicated currents and on the BT readings.

The technique of using the geomagnetic electrokinetograph with regular Bathythermograph readings and, if possible, with accurate and frequent position determinations, makes it possible to survey the surface currents over large areas rather rapidly. This is shown frequently elsewhere, and as can also be seen from this preliminary report on the Marine Laboratory Grand Cayman Cruise. The rapidity of such a survey also makes it possible to follow the different types of pulsations in the current system.

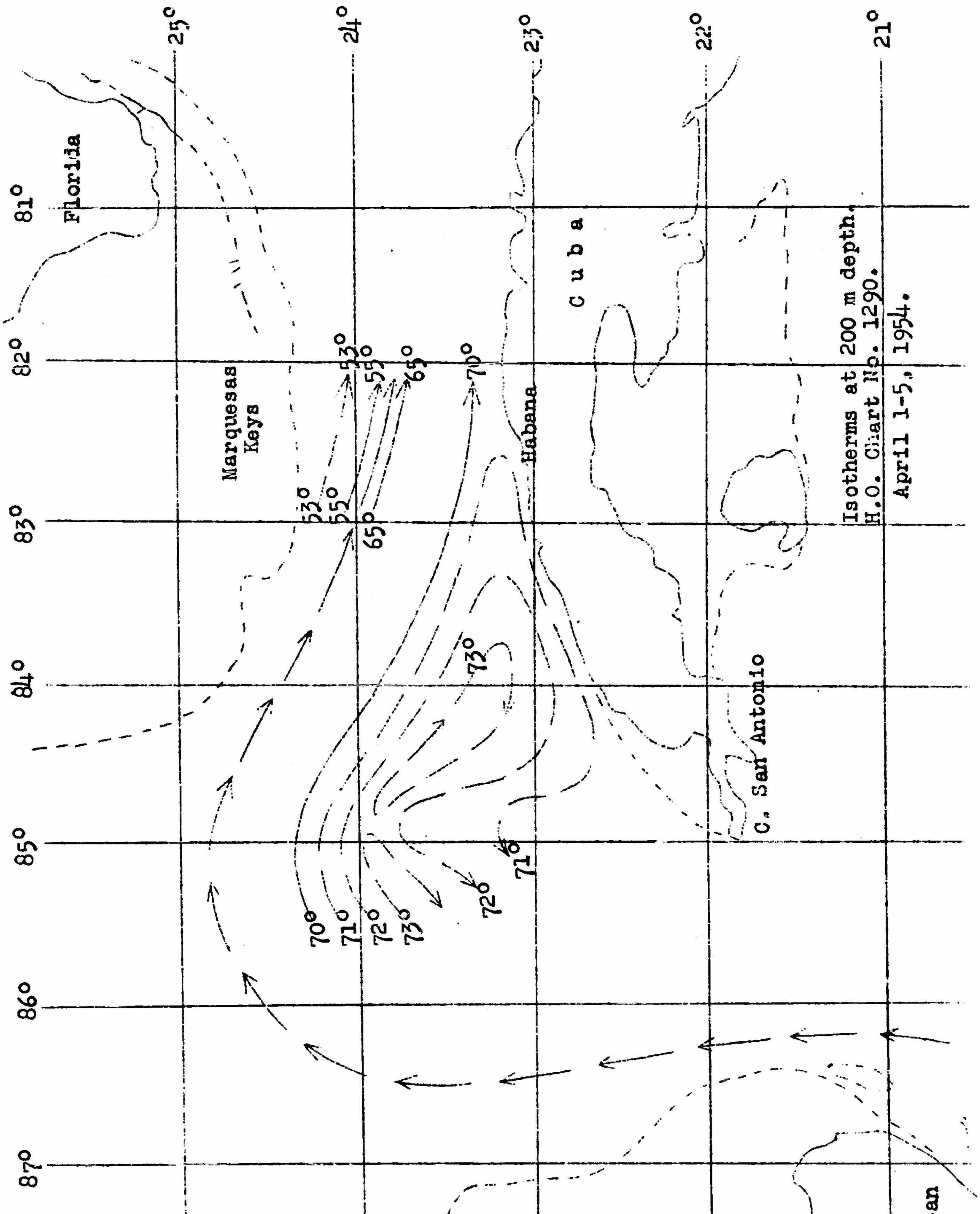
The hydrographic stations, which will be reported in the next semiannual report, will furnish additional important information on the currents, especially subsurface currents and, of course, on the T-S correlation, and so forth. However, the existence of current fluctuations, or an actual pulsation, makes it necessary to try to make the regional studies as synoptic as possible. For this purpose, if only major surface water movements are of interest, we feel that, several rapid GEK-BT sections during a certain period of time can give more information than one single hydrographic section covering a longer period of time. The only observations needed in addition to the GEK-indicated surface currents and BT readings are the subsurface currents; the bathypitotmeter seems capable of solving this problem. In this Laboratory the idea of towing two electrical logs at different depths has been developed to obtain reliable observations on subsurface currents. It is hoped that this new technique can be tested at sea during the coming semiannual period.

In general, this Laboratory feels that, besides proper theoretical studies, the time is ripe for rather extensive and really continuous studies of the water movements, for example, in the Yucatan Channel, or between



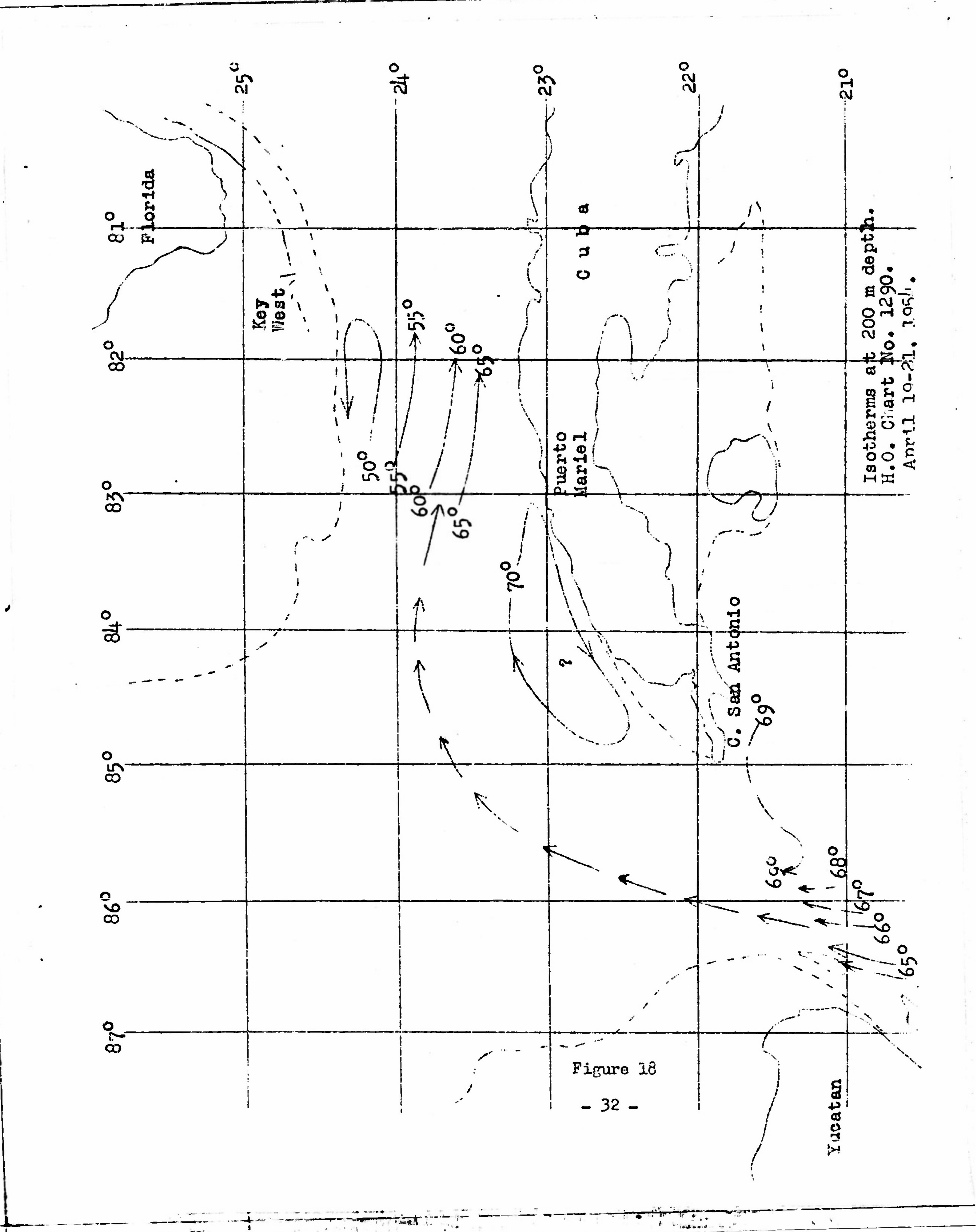
Isotherms at 200 m depth.
H.O. Chart No. 1290.

Figure 16



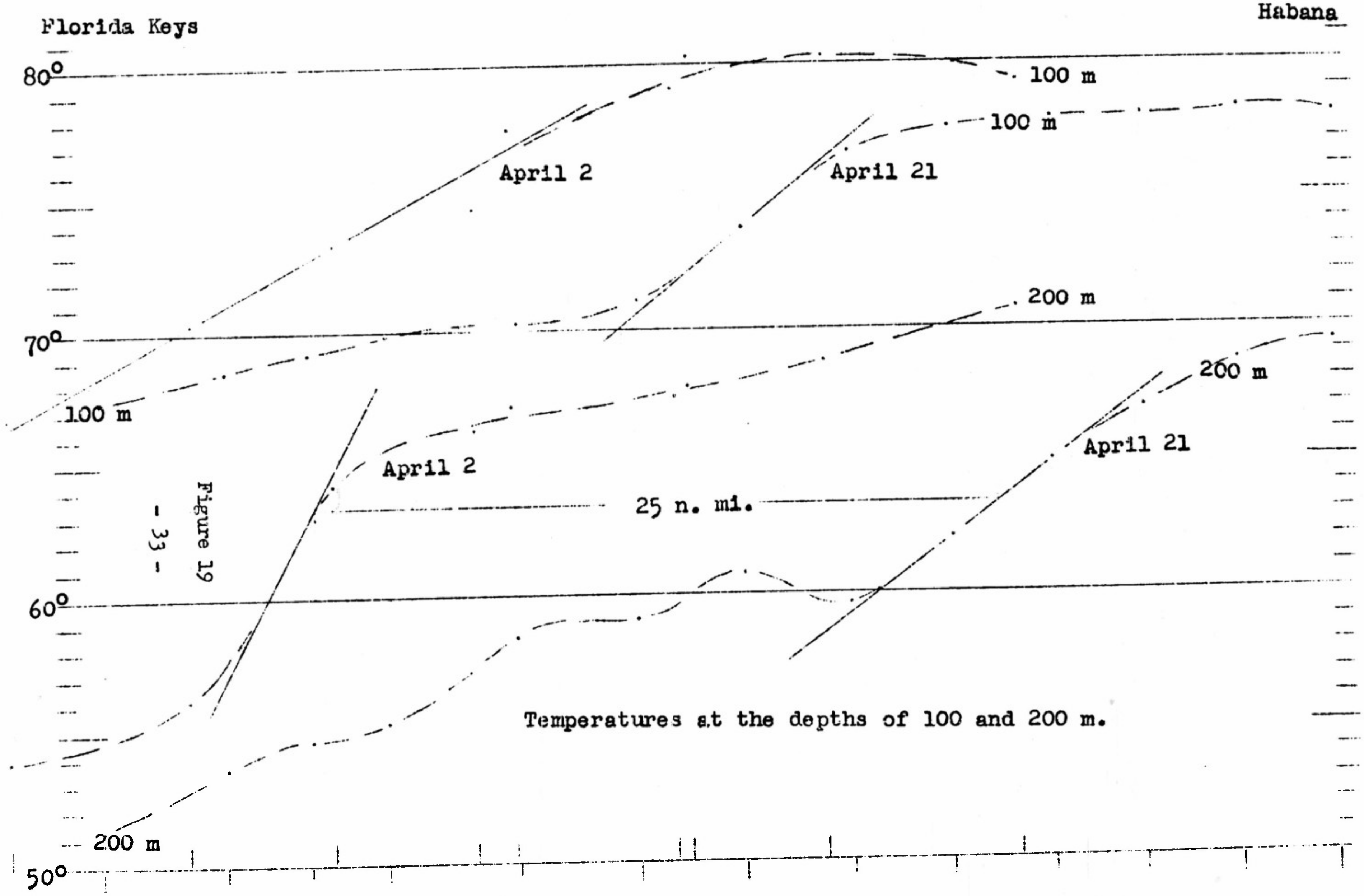
87°
86°
85°
84°
83°
82°
81°
25°
24°
23°
22°
21°
Florida
Marquesas Keys
Habana
Cuba
C. San Antonio
Yucatan
53°
55°
65°
70°
71°
72°
73°
Isotherms at 200 m depth.
H.O. Chart No. 1290.
April 1-5, 1954.

Figure 17



25°
24°
23°
22°
21°
81°
82°
83°
84°
85°
86°
87°
Florida
Key West
Cuba
Puerto Mariel
C. San Antonio
Yucatan
50°
55°
60°
65°
70°
69°
68°
67°
66°
?
Isotherms at 200 m depth.
H.O. Chart No. 1290.
April 10-21, 1951.

Figure 18



Temperatures at the depths of 100 and 200 m.

Figure 19

the Florida Keys and Habana, or between Miami and Gun Cay. The financial limitations have made these studies practically impossible so far; nevertheless, we believe that this is the goal towards which we have to work. Otherwise, the true character of the fluctuations in the current systems cannot be understood.

PERTINENT INFORMATION OF THE GEK FIXES

On the following pages the GEK surface current observations are give The K-factors have not been computed; actually, in most cases we had no method of computing the mean value of the K-factor as we are accustomed to doing between Miami and Gun Cay. Therefore, the true surface currents are slightly greater than indicated in the following tables.

Cruise	Date	Time EST	Station No.	Lat. N.	Long. W.	Speed cm/sec	Dir. True	Obs.
P-420	IV 1	1624	5	—	—	—	—	Hydro
		1855	6	24 12.5	82 21.7	60	136	Hydro
		2200	7	24 05.5	82 23.5	79	100	—
		2245	8	23 59.2	82 26.5	80	094	Hydro
	IV 2	0150	9	23 53.5	82 26.5	113	087	—
		0300	10	23 49.2	82 31.0	114	095	Hydro
		0857	11	23 46.0	82 25.2	91	083	—
		1005	12	23 41.3	82 32.0	86	082	Hydro
		1615	13	23 39.5	82 27.5	82	102	—
		1720	14	23 35.8	82 33.7	57	104	Hydro
		2200	15	23 26.5	82 29.0	52	099	—
		2333	16	—	—	—	—	Hydro
	IV 4	1850	20	22 48.0	84 01.5	47	243	Hydro
		2045	22	22 51.0	84 08.0	46	245	—
		2227	23	—	—	—	—	Hydro
	IV 5	0220	24	23 02.5	84 26.0	42	278	—
		0406	25	—	—	—	—	Hydro
		0743	26	23 16.3	84.45.7	60	333	—
		0850	27	23 23.8	84 54.5	32	308	Hydro
		1630	28	23 32.7	84 57.7	27	246	—
		1725	29	23 39.5	84 58.7	33	237	Hydro
		2145	30	23 31.0	85 02.0	11	202	—
	IV 6	1000	32	21 57.5	85 00.5	23	335	—
		1100	33	21 49.5	84 58.5	21	277	—
		1155	34	21 46.2	84 53.0	30	271	—
		1300	35	21 45.0	84 47.0	34	308	—
		1400	36	21 44.0	82 41.0	36	268	—
		1500	37	21 42.5	84 34.5	68	261	—
		1620	39	21 41.0	84 26.0	74	255	—
		1715	40	21 39.5	84 19.0	83	246	—

Cruise	Date	Time EST	Station No.	Lat. N.	Long. W.	Speed cm/sec	Dir. True	Obs.
P-420	IV 6	1815	41	21 38.0	84 12.0	72	260	—
		1920	42	21 37.0	84 05.5	62	276	—
		2030	43	21 35.7	84 00.0	58	302	—
		2130	45	21 34.5	83 54.5	50	304	—
		2230	46	21 33.0	83 47.0	41	328	—
		2330	47	21 31.2	83 39.0	25	347	—
	IV 7	0015	48	21 30.0	83 31.5	27	003	—
		0115	49	21 28.3	83 24.0	25	018	—
		0235	50	21 27.0	83 17.0	19	082	—
		0345	51	21 25.2	83 10.5	13	194	—
		0500	52	21 24.0	83 04.0	31	142	—
	IV 8	2015	53	21 32.0	81 39.0	9	052	—
		2040	54	21 30.0	81 39.0	4	264	Hydro
	IV 9	0035	55	21 19.8	81 41.0	10	108	—
		0155	56	21 09.0	81 41.3	15	320	—
		0315	57	20 59.0	81 42.0	31	302	—
		0435	58	20 49.0	81 43.0	28	299	Hydro
		0830	59	20 39.0	81 45.3	21	243	—
		0950	60	20 27.5	81 42.0	28	204	—
		1110	61	20 17.5	81 40.0	35	269	—
		1235	62	20 06.8	81 38.0	19	174	Hydro
		1550	63	19 55.5	81 38.0	33	194	—
		1650	64	19 47.5	81 37.2	51	207	—
		1810	65	19 37.5	81 36.5	29	202	—
		2207	66	19 28.0	81 31.0	13	175	Hydro
	IV 11	0645	67	19 13.5	81 25.5	9	012	—
		—	68	—	—	—	—	Hydro
		1100	69	19 06.0	81 31.0	47	102	—
		1210	70	18 59.5	81 40.5	29	089	—
		1310	71	18 53.5	81 46.5	17	052	—
		1410	72	18 47.0	81 52.5	27	002	—
		1510	73	18 40.5	81 58.0	42	353	—
		1610	74	18 34.5	82 04.0	51	338	Hydro
		2000	75	18 32.0	82 11.0	3	203	—
		2100	76	18 26.5	82 17.0	17	247	—
	IV 12	0000	78	18 09.5	82 35.0	11	312	—
		0100	79	18 04.0	82 41.0	24	344	Hydro
		0510	80	18 00.0	82 50.0	39	305	—
		0610	81	17 54.0	82 56.5	52	280	—
		0700	82	17 49.5	83 01.0	41	259	—
		0750	83	17 44.5	83 06.5	31	286	—
		0845	84	17 39.0	83 12.5	44	292	Hydro
		1330	85	17 34.5	83 23.5	36	271	—
		1430	86	17 29.0	83 29.5	34	271	—
		1530	87	17 23.5	83 35.5	18	272	—

Cruise	Date	Time EST	Station No.	Lat. N.	Long. W.	Speed cm/sec	Dir. True	Obs.
P-420	IV 12	1615	88	17 19.0	83 41.0	11	235	—
		1700	89	17 14.0	83 46.5	18	232	Hydro
		2215	90	17 08.0	83 53.5	16	268	—
		2320	91	17 02.0	84 00.0	7	298	—
	IV 13	0030	92	16 56.0	84 06.0	9	303	—
		0200	93	16 47.5	84 14.5	5	293	—
		0325	94	16 39.0	84 22.5	4	175	Hydro
		0645	95	16 28.5	84 33.0	11	060	—
		0815	96	16 18.5	84 42.5	8	288	—
		0945	97	16 10.0	84 51.0	24	296	Hydro
	IV 19	1615	104	20 39.0	86 47.5	43	349	—
		1715	106	20 43.5	86 40.0	59	356	—
		1815	108	20 47.0	86 32.5	63	021	—
		1915	110	20 51.0	86 26.0	81	037	—
		2015	112	20 54.0	86 19.0	54	016	—
		2115	114	20 59.0	86 12.0	26	079	—
		2215	116	21 03.5	86 04.5	13	095	—
		2315	118	21 08.0	85 57.0	31	339	—
	IV 20	0115	120	21 13.5	85 47.5	49	002	—
		0215	122	21 18.0	85 40.5	19	269	—
		0315	124	21 22.0	85 33.0	15	268	—
		0415	126	21 25.0	85 26.5	46	244	—
		0515	128	21 27.5	85 19.0	39	231	—
		0615	130	21 30.0	85 12.0	60	238	—
		0735	132	21 32.5	85 03.5	70	233	—
		0907	133	21 41.5	84 56.0	59	284	—
		1010	134	21 48.5	84 57.5	27	345	—
	IV 21	0855	135	23 08.0	82 47.5	21	063	—
		1000	137	23 14.5	82 43.7	61	082	—
		1100	139	23 21.0	82 39.5	72	097	—
		1200	141	23 27.0	82 35.0	118	115	—
		1300	143	23 33.5	82 30.0	121	095	—
		1400	145	23 39.5	82 22.5	149	104	—
		1500	147	23 46.0	82 11.5	130	104	—
		1600	149	23 52.0	81 59.0	37	094	—
		1700	151	23 58.3	81 53.0	04	134	—
		1800	153	24 04.5	81 48.5	16	010	—
		1900	155	24 11.0	81 44.3	25	039	(?)
		2000	157	24 16.5	81 40.7	40	291	(?)

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